THE ARCHAEOLOGY AND TAPHONOMY OF THE HERON EDEN SITE, SOUTHWESTERN SASKATCHEWAN

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ABSTRACT

Heron Eden (EeOi-11) is a Cody complex bison kill-butchery site located in southwestern Saskatchewan. The bison bone has been radiocarbon dated to approximately 9000 years ago. This site, along with neighboring sites of similar age such as the Dunn, Niska, Napao, and Fletcher sites, are located in similar environments with a semi-arid climate, grassland vegetation, and soil formed on sandy sediments of glacial origin.

The site is located on a small knoll in a cultivated field on the northwestern periphery of the Great Sand Hills. It is situated near the periphery of a small glacial lake basin in an area identified as a glacio-lacusterine delta. Cultivation has reduced both the horizontal and vertical extent of the bone bed. Excavations were initiated in an attempt to salvage a portion of the remaining intact bone bed. Overall, the general preservation of the faunal material was poor. The analysis of the faunal assemblage was undertaken to determine the degree to which the bone bed composition and distribution could be attributed to intention cultural activity.

The Heron Eden site represents the most northern Cody complex site yet found on the Great Plains. The limited reconstruction of the procurement strategy exhibited at the site generally corresponds to the patterns observed at other Paleoindian bison kill-butchery sites.

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LIST OF ABBREVIATIONS

B.P.	before present
NISP	number of identified specimens
MNE	minimum number of elements
MAU	minimum animal units
MNI	minimum number of individuals
modified NISP	modified number of identified specimens
VC Sand	very coarse sand
C Sand	coarse sand
M Sand	medium sand
F Sand	fine sand
VF Sand	very fine sand
dbs	depth below surface
SAS	Saskatchewan Archaeological Society
%MAU	percent MAU
MGUI	modified general utility index
(S)MAVGTP model	standardized, modified average total products utility
V.D.	bone volume density
s.d.	standard deviation
N	number of
Min.	minimum
Max.	maximum
r	Spearman's rho
P	probability
N	number of ranks
%CN	percentage completeness
PP	number of portions preserved
PP/SP	number of portions per specimen
PD	number of portions defined
%Complete	percentage complete
%Difference	percentage difference
dP3	third deciduous premolar
dP4	fourth deciduous premolar
M1	first molar
M2	second molar
M3	third molar

CHAPTER 1

INTRODUCTION

1.1 Statement of Objectives

In the summer of 1989, an archaeological testing project uncovered a Cody complex bison kill-butchery site in southwestern Saskatchewan. Although the site had been under cultivation for some time, a portion of the bone bed remained intact. Cultivation has had a serious impact on both the individual faunal specimens and the extent of the bone bed. A series of small scale excavations were carried out between 1989 and 1992 to salvage as much of the site as possible. The site was radiocarbon dated to approximately 9000 years before present (B.P.). Three of the eight complete projectile points were found within the intact portion of the bone bed. These points, identified as of the Scottsbluff and Eden types of the Cody complex, provide additional support for the antiquity of the site.

In total, 82 square meters have been excavated. Overall, the distribution of faunal materials is characterized by a mixed scatter of complete and fragmentary specimens. The bison bone recovered is generally weathered and fragmented. Although the general preservation of bone material at the site was poor, some elements are exceptionally complete. Much variability is observed in the degree of bone preservation, both horizontally and vertically, and in the distribution of the faunal assemblage. Therefore, weathering has variably affected the faunal assemblage.

Understanding the formation of an archaeological bone bed involves reconstructing the processes that have gone into the development of that

bone bed. Investigations into the type and seasonality of the death assemblage, herd population structure, cultural modification, skeletal element frequencies, and post-occupational processes all contribute to interpretations of cultural utilization. However, there are problems in distinguishing between the effects of multiple cultural and natural processes, as each subsequent modification can bias the effect of previous processes. Taphonomic analysis provides a means for separating these biases.

The object of this thesis is to assess how the procurement strategy exhibited by the Heron Eden bone bed corresponds to patterns observed at other Paleoindian kill-butchery sites of this general age. This thesis provides a taphonomic analysis of the faunal assemblage from the Heron Eden site and evaluates the degree to which bone bed composition and distribution can be attributed to intentional cultural activity. This research goal will be looked at in two ways. The first involves the reconstruction of the bison herd population structure represented by the faunal assemblage. These analyses support inferences regarding the type and seasonality of the death assemblage, animal counts, gender structure, age structure and some general comments on the taxonomic placement of the Heron Eden site bison. The second is to evaluate the degree to which the content and structure of the faunal assemblage can be attributed to post-occupational processes. This includes a general assessment of attritional processes, observations regarding the variability in bone fragmentation, and evaluation of skeletal part representation.

1.2 Chapter Outline

The introduction presents an outline of each chapter in this thesis. Chapter two provides background information on the location and environment of the Heron Eden site. Discussion of site physiography provides the context for the bone bed under study. This is followed by a description of the sediments and stratigraphy present at the site. Projectile point typology provides interpretations of site type and the time frame for site occupation. Radiometric dates are presented to establish the age of the site. A short discussion on the cultural context is then presented.

Chapter three outlines the discovery of the site and a history of the investigations that followed. The excavation methods used to expose, document, and remove the faunal material are presented along with the computer coding and identification procedures. Definitions of the basic terminology used in this thesis follows a brief discussion of the analytical procedures.

Chapter four begins with an introduction to the Heron Eden site faunal material. Since this chapter examines the population dynamics of the herd represented by the faunal assemblage, quantitative bone counts including number of identified specimens (NISP), minimum number of elements (MNE), minimum animal units (MAU), and minimum number of individuals (MNI) are presented here. The distribution of the faunal remains will be examined by weight and a modified NISP per square meter. Comments on the dispersal of faunal material and lack of features will be included. Gender determination will be based on the measurements of carpals and tarsals, metapodials, and long bones. These determinations will then be used for comments on herd structure and species identification. A detailed study of the lower dentition is then presented to infer the bison

population structure and the type of mortality event represented. This analysis is also used to infer the seasonality of site use.

Chapter five begins with a short introduction to taphonomy. Weathering stages are then outlined and used to describe the generally poor condition of the faunal material. Other processes of attrition are then considered. The percentage completeness of select elements is used to assess the effects of cultivation on the completeness of skeletal elements in the plowzone. This measure is also used to assess the presence of differential bone fragmentation within the paleosol. The paleosol skeletal part frequencies are then presented using minimum animal units (MAU). These are compared to an economic utility index and bone mineral densities derived for bison. Similarly, select groups of elements are compared to utility and density to assess if the skeletal part frequencies are the result of cultural or natural processes, or a combination of both. Carnivore activity is also assessed considering long bone element frequencies.

Chapter six summarizes the results of the Heron Eden site analyses and provides a short discussion on Paleoindian bison procurement. The procurement strategy and seasonality of select Paleoindian bison kill-butchery sites of similar age are then presented. This is followed by a restatement of the research objectives. Conclusions from this study are then presented culminating with interpretations regarding the intentional cultural activity exhibited by the Heron Eden faunal assemblage.

CHAPTER 2

REGIONAL ENVIRONMENT AND SITE BACKGROUND

2.1 Site Location and Environment

The Heron Eden site is located in southwestern Saskatchewan approximately 13 km south of Prelate (Figure 2.1). The site is situated in a cultivated field a few kilometers to the northwest of the Great Sand Hills. More specifically, the legal land location is NW NW quarter of Section 35, Township 20, Range 25, west of the third Meridian.

This area of Saskatchewan is characterized by a cold steppe, semi-arid climate. Some years have more moisture when the cold sub-humid climate from further north shifts into the region (Townley-Smith 1980a:20). However, semi-arid conditions generally prevail. The temperature is highly variable, with wide variations between seasons and years. There are also wide variations in temperature between day and night and from day to day in all seasons (Townley-Smith 1980a:22). The average annual wind speed is moderately high, prevailing from the northwest. Precipitation is low within this type of climatic regime but there is much variability (Chakravarti 1969:60). The potential evapo-transpiration is typically greater than the precipitation received, making the climate semi-arid (Townley-Smith 1980a:22).

The region has grassland vegetation and grassland soils. The latter are generally classified as brown chernozemic or dark coloured grassland soils (Moss and Clayton 1969:72). Soils, in the area of the Heron Eden site,

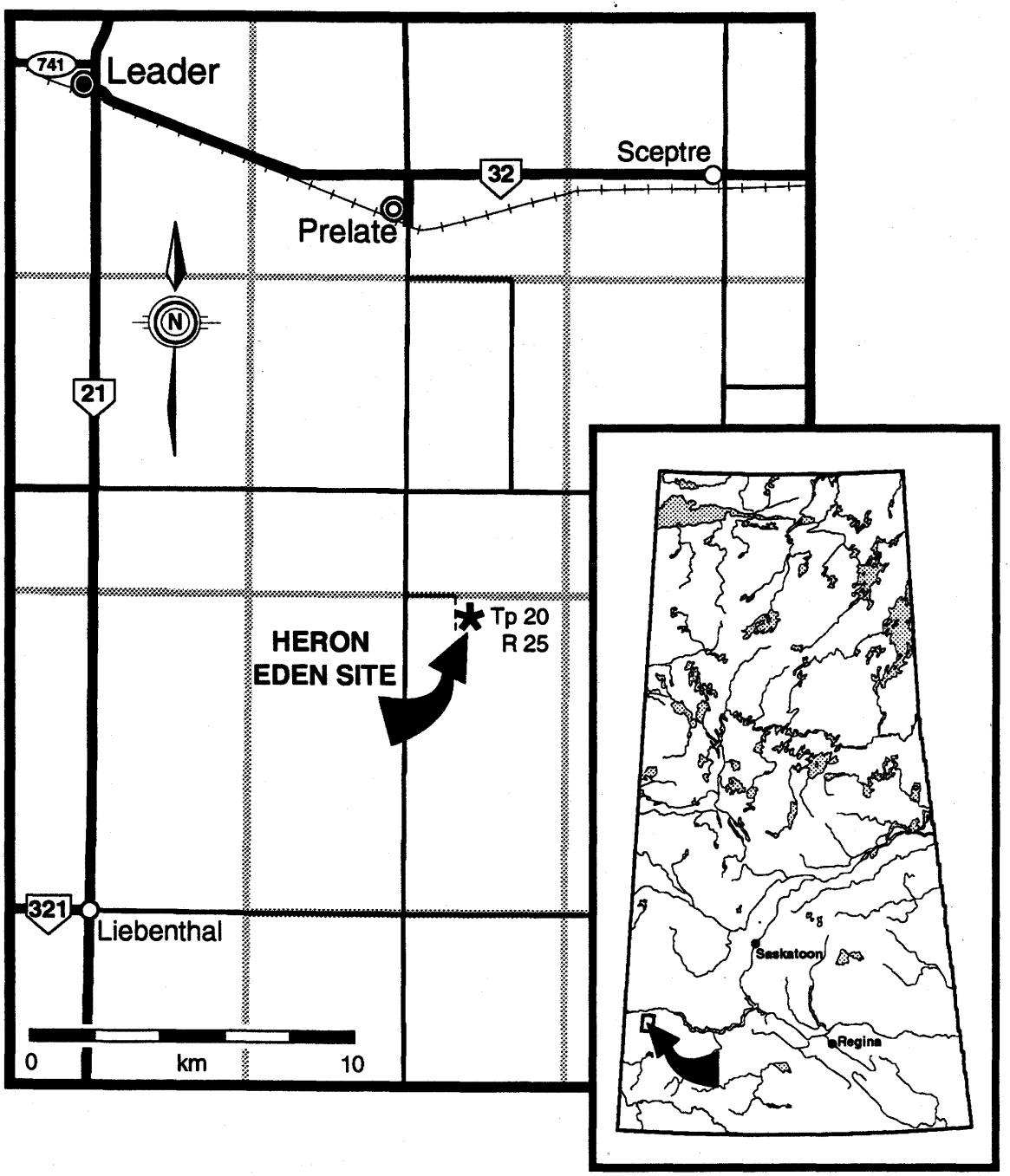


Figure 2.1 Location of the Heron Eden site (EeOi-11) in Saskatchewan.

belong to the Birsay-Hatton group. These are brown soils having very fine sandy loam to sandy loam surface textures (Saskatchewan Institute of Pedology 1990:7.2). They are rapidly draining soils which are susceptible to water and wind erosion.

Common vegetation includes a variety of grasses, forbs, shrubs, and deciduous trees (Townley-Smith 1980b; Mollard et al. 1990: Appendix B; Saskatchewan Environment and Public Safety 1991:10-11). The taxonomic nomenclature is taken from Budd and Best (1969). The grasses include spear grass (*Stipa comata*), wheat grasses (*Agropyron sp.*), blue grama (*Bouteloua gracilis*), and june grass (*Koeleria cristata).* The forbs include hairy golden-aster (*Chrysopsis villosa*), skeletonweed (*Lygodesmia juncea*), yellow flax (*Linum rigidum*), sand dock (*Rumex venosus*), and lance-leaved psoralea (*Psoralea lanceolata*). The shrubs include wolf-willow (*Elaeagnus commutata*), creeping juniper (*Juniperus horizontalis*), bearberry (*Arctostaphylos uva-ursi*), rose (*Rosa sp.*), sagebush (*Artemisia cana*), snowberry (*Symphoricarpos occidentalis*), and choke cherry (*Prunus virginiana*). The deciduous trees include the plains cottonwood (*Populus sargentii*) and the trembling aspen (*Populus tremuloides*).

A list of vertebrate fauna for the Great Sand Hills includes five species of amphibians, 73 species of birds and 19 species of mammals (Epp and Waker 1980). Pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and white-tail deer (*Odocoileus virginianus*) are the dominant ungulates. Bison (*Bison bison*), once present in the area, have been largely extirpated here, as elsewhere in North America (Maher 1969:82). Epp and Waker (1980:84) observe that the Great Sand Hills contain some animals which are also adapted to a variety of other habitats. These include the grassy plains that surround the hills, the shrubby habitats

found in hilly areas and stream valleys, and the parklands to the north. Thus the Great Sand Hills area supports a wide variety of plants and animals in a relatively small area.

2.2 Site Physiography

The Great Sand Hills region, including the Heron Eden site, is located within the physiographic division known as the Great Plains Province, Alberta Plateau Region (Richards 1969:40) or Alberta High Plains (Acton et al. 1960). Regionally, this area is part of the Bigstick Lake Plain (Acton et al. 1960) and is specifically denoted as the Great Sand Hills ecoregion (Padbury and Acton 1994). In the northern portion of the Great Sand Hills aeolian sands generally overlie thick deposits of glacio-lacustrine and fluvioglacial sediments (David 1968:156). Glacial Lake Stewart Valley (David 1964), a meltwater lake, was located in this region sometime before 11,700 years ago (Clayton and Moran 1982). In the northern part of the Great Sand Hills region sandy deltas developed along the margins of temporary glacial lakes shortly after glacial retreat (Mollard et al. 1990:12). Therefore, the aeolian sand is underlain by fine-grained sand and lacustrine silt and clay (David 1969:61).

The Heron Eden site is situated near the northern edge of a small basin characterized by flat to gently undulating terrain. This area is identified as a glacio-lacustrine delta with a lake strandline located to the west, north, and east (Saskatchewan Research Council 1987). A cut occurs in the ridge which is locally known as "the gap". The gap formed when a glacial lake that existed south of the strandline on ice-retreat broke through to the north and the lake drained into the ancestral South Saskatchewan River (Walter Kupsch, personal communication 1992).

The Heron Eden site is located adjacent (within the same legal section) to a landform, classified as sandflats, located in the north section of the Great Sand Hills (Townley-Smith 1980a: Figure 4.3a and Table 4.3). Sandflats are described as areas of level topography with very low dunes under two meters in height. They have a very low frequency of dunes and no active sand. These flat or nearly flat sand deposits typically have weakly developed soil profiles. The soils in the area are described as Birsay-Hatton soils. These are brown soils formed in a mixture of loamy lacustrine (Birsay) and sandy fluvial (Hatton) materials (Saskatchewan Institute of Pedology 1990). More specifically, they are called ByHt 4, being mainly orthic Birsay soils with orthic Hatton soils, and calcareous Birsay soils on upper slopes and knolls. This is a rapidly draining soil with a high to very high susceptibility to wind erosion and a low susceptibility to water erosion if disturbed (Saskatchewan Institute of Pedology 1990:7.2).

The Heron Eden site is located on a small, low knoll in a cultivated field. The surrounding area is characterized by flat to gently undulating sandflats. The nearest prominent landform, a lake strandline feature, is located approximately one kilometer north of the site. Thus, there are no topographic features in the immediate area of the Heron Eden site to offer any indication of the bison procurement method used. Long term cultivation in the site area has artificially leveled the surface topography. It is likely that the bone bed itself is resistant to erosion so as to cause the site location to become a small knoll. The current extent of the paleosol (see Chapter 3) is what is expectected if the bone bed inhibited erosion from the prevailing northwesterly winds.

2.3 Site Stratigraphy

The stratigraphy of the Heron Eden excavation area is relatively straightforward because there is only one occupation horizon immediately beneath the cultivation layer (Figure 2.2). The plowzone was approximately 10 cm to 20 cm thick and was made up of light brown sandy loam, intermixed with portions of the cultivated paleosol and organics from current farming activity. The paleosol is located immediately below the plowzone. The occupation horizon (the portion of the paleosol which contains cultural material) was typically 10 cm to 25 cm thick. The dark brown occupation horizon has a clay loam to loam texture and is quite organic and calcareous. Much disturbance from rodent activity was observed at the site (Figure 2.3), displacing the cultural material and the sedimentary matrix both horizontally and vertically. Beneath the occupation horizon is an extensive deposit of light brown sandy loam, which will be subsequently referred to as the level three sediment.

Figure 2.2 Excavation unit wall profile at the Heron Eden site.

Figure 2.3 Excavation unit wall profile showing rodent disturbance.

In 1989 excavation units 102N 107E and 102N 108E were tested to 120 cm below the surface (dbs). Bulk sediment samples were collected from a sampling column in the south wall of Unit 102N 108E (Figure 2.4). All of the sediment samples are designated by the profile wall of the excavation unit from which they were sampled. In 1992 bulk samples were collected from the profile walls of a number of excavation units (Figure 2.4). Additional samples were then collected from the windward and leeward sides of an active dune in the northern Great Sand Hills area. Portions of these data have been presented elsewhere (Corbeil 1992, 1993; Linnamae and Corbeil 1992).

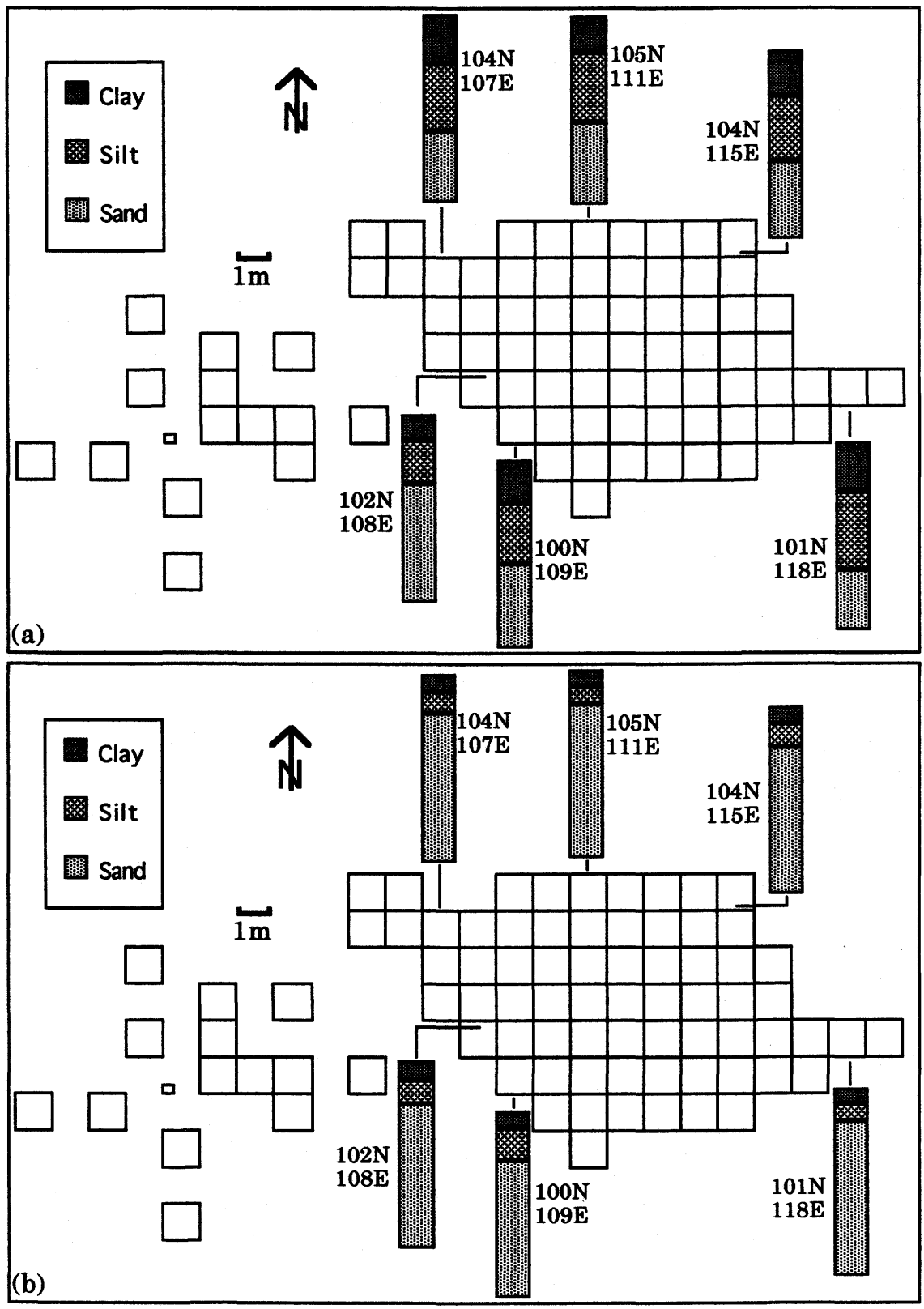


Figure 2.4 Location and composition of sediment samples from a) the paleosol (occupation horizon) and b) the level three sediments.

The particle size distributions of the sediment samples were determined using the facilities of the Saskatchewan Soil Survey, University of Saskatchewan. The samples underwent chemical pre-treatment prior to determining the grain size distribution of sand by wet sieving and the proportions of silt and clay by the pipette method. The percentages of sand, silt, and clay are presented in Table 2.1. These data correspond to those previously presented in Figure 2.4.

Table 2.1 Sand, silt, and clay percents for sediment samples from the Heron Eden site and an active dune.

	phi	0-4	8	14
Unit	Level	%Sand	%Silt	%Clay
104N 107E	2	37.7%	36.4%	25.9%
104N 107E	3	80.0%	10.6%	9.4%
105N 111E	2	44.3%	36.0%	19.6%
105N 111E	3	81.7%	9.3%	9.0%
104N 115E	2	41.9%	34.5%	23.6%
104N 115E	3	78.9%	11.9%	9.2%
101N 118E	2	31.9%	42.0%	26.0%
101N 118E	3	82.7%	9.2%	8.0%
100N 109E	2	45.6%	31.8%	22.6%
100N 109E	3	73.5%	17.4%	9.0%
102N 108E	2	63.6%	23.1%	13.3%
102N 108E	3I	77.2%	13.0%	9.8%
102N 108E	3VI	72.0%	18.9%	9.1%
102N 108E	3XII	70.8%	20.2%	9.1%
Active Dune	Lee	100.0%	0.0%	0.0%
Active Dune	Windward	99.8%	0.2%	0.0%

The texture of the sediments is more variable in the paleosol samples. Excluding sample 102N 108E, the texture ranges from loam to clay loam. The sandy loam texture of sample 102N 108E is anomalous considering the remainder of the paleosol samples. The different sampling technique used in

the collection of this sample can account for this discrepancy. In 1992 small bulk sediment samples, 100 to 200 grams, were collected from areas of no observable disturbance. In 1991, one to two kilogram bulk samples were collected. Due to the great amount of disturbance noted in the paleosol, it is possible that this large paleosol sample, and the level three sample directly beneath, contain intrusive sediments. Inadvertent inclusion of the underlying sediments in the paleosol sample could produce this discrepancy.

The samples collected from the level three sediments have less variable textures, which oscillate between loamy sand and sandy loam. This includes three level three samples from the sedimentary column in excavation unit 102N 108E. Figure 2.5 presents the cumulative percent of sand, silt, and clay from the sedimentary column samples. While the increase in percent sand is observed for the sample between 20 cm and 30 cm, a consistent decrease in percent sand occurs for the deeper samples. This coincides with an increase in the percent silt, while the clay content remains similar.

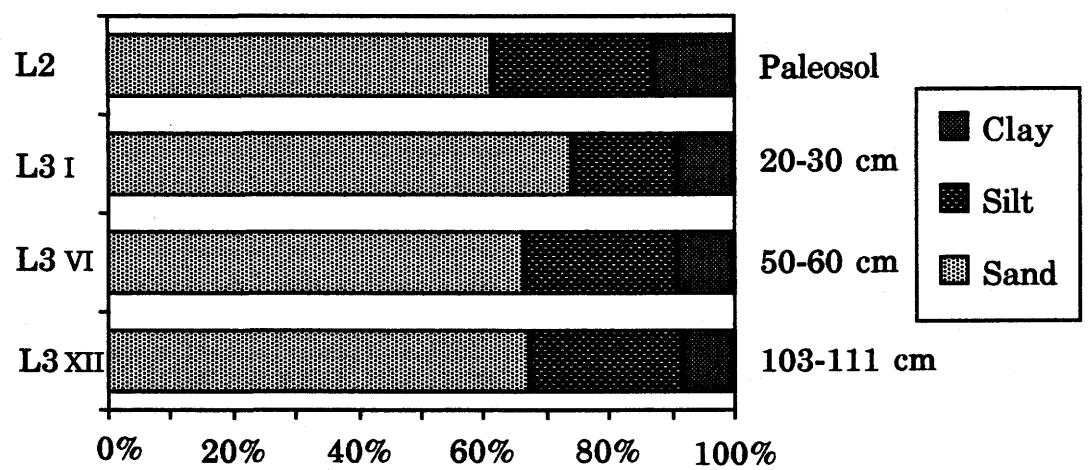


Figure 2.5 Cumulative percent of sand, silt, and clay by level and depth in the excavation unit 102N 108E sedimentary sample profile.

Table 2.2 presents the grain size distribution of the sand fractions for the sediment samples. These data, along with the silt and clay fractions, are used for cumulative particle size distribution curves (Figure 2.6). Two samples, the paleosol sample and the Level 3 sample, from 102N 108E are anomalous when compared to the reminder of the distribution curves. Because the remainder of the sediment samples cluster into distinct groups and because of the difference between the sediment sampling procedures discussed previously, these samples are considered biased and are not included in subsequent discussions.

Table 2.2 Particle grain size distribution of the sand fraction for sediment samples from the Heron Eden site and an active sand dune.

	phi	0	1	2	3	4
Unit	Level *	%VC sand	%C sand	%M sand	%F sand	%VF sand
104N 107E	2	2.5%	1.2%	0.3%	6.8%	28.4%
104N 107E	3	0.0%	0.0%	0.0%	13.3%	63.4%
105N 111E	2	0.7%	0.1%	0.1%	9.5%	33.5%
105N 111E	3	0.0%	0.0%	0.0%	22.1%	59.1%
104N 115E	2	1.4%	0.3%	0.1%	7.7%	32.4%
104N 115E	3	0.0%	0.0%	0.0%	9.4%	69.3%
101N 118E	2	0.1%	0.1%	0.0%	7.5%	22.4%
101N 118E	3	0.0%	0.0%	0.0%	10.2%	72.0%
100N 109E	2	0.2%	0.1%	0.1%	9.0%	35.2%
100N 109E	3	0.0%	0.0%	0.0%	13.3%	59.6%
102N 108E	2	0.3%	0.1%	0.1%	11.1%	50.6%
102N 108E	3I	0.0%	0.0%	0.0%	12.2%	59.8%
102N 108E	3VI	0.0%	0.0%	0.0%	4.8%	61.7%
102N 108E	3XII	0.2%	0.1%	0.2%	5.9%	61.0%
Active dune	Lee	0.0%	0.0%	0.0%	80.6%	19.4%
Active dune	Windward	0.0%	0.0%	0.0%	57.9%	41.8%

*Abbreviations: VC=very coarse, C=coarse, M=medium, F= fine, and VF=very fine.

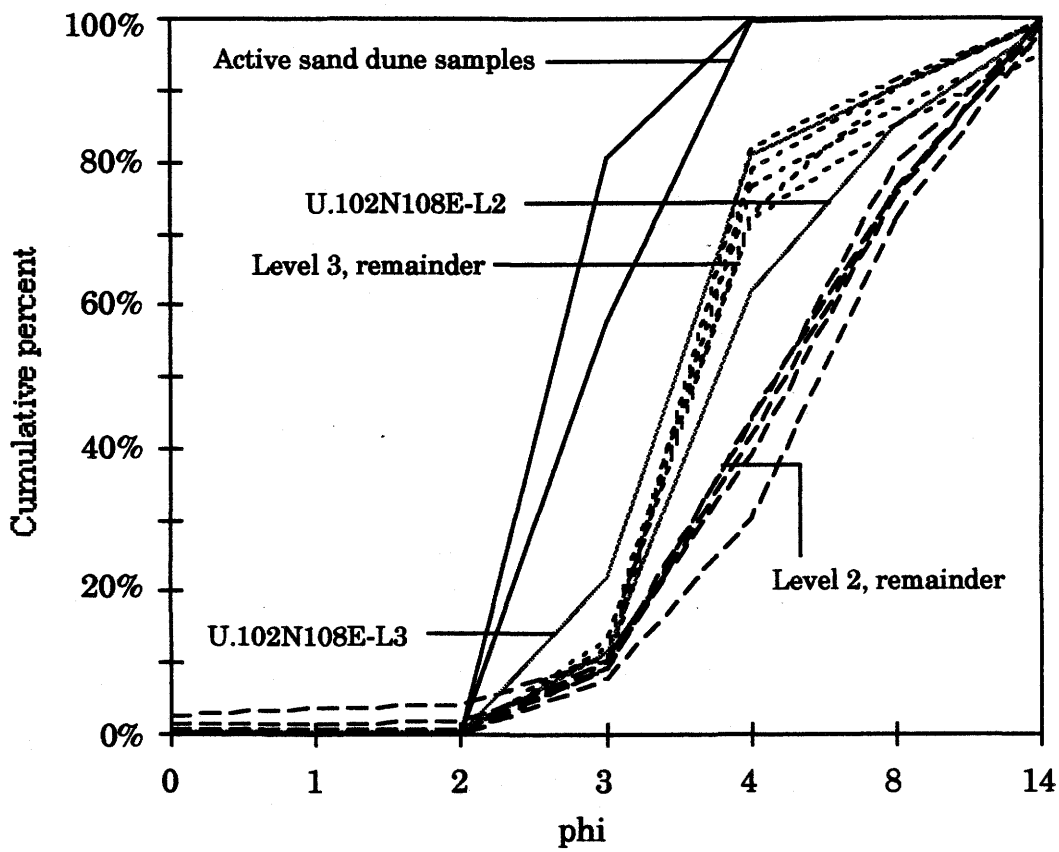


Figure 2.6 Cumulative particle size distribution curves for the paleosol and level three sediments from the Heron Eden site and an active sand dune.

The three sample groups, or sediment types, can be distinguished from one another by the distinctive patterns of the cumulative particle size distribution curves (Figure 2.6). This shows that the best sorted sediments are the sands from the active sand dunes. Less sorted are the level three sediments which underlie the occupation horizon. The least sorted are the samples from the occupation horizon (or paleosol) which contain more fine grained silts and clays.

A comparable situation was discussed by David (1971). In this situation, deltaic sediments, which were the least sorted, represent the parent material from which the dune sands, which were the best sorted,

were derived. Soil development on the aeolian sediments increased the amount of silts and clays thus reducing the level of sorting in the paleosol sediments (David 1971:295).

In the case of the Heron Eden site, the particle size distribution curve for the parent material is unknown. From the previous discussions of site location, physiography, and soils; the parent material of the Heron Eden site sediments is inferred to consist of poorly sorted deltaic materials. If the parent material is the least well sorted and the dune sand is the best sorted, then the level three sediments display intermediate sorting. This suggests that several types of deposition and transportation energies have affected the sediments. A comparable situation has been noted for a braided bar in a river system with no gravels, where a combination of highly selective aeolian action and unidirectional water flow or wave action produces medium level sorting in the sandy sediments (Leslie Amundson, personal communication 1995). Thus, at the Heron Eden site, a combination of aeolian activity and fluvial and/or wave action can be inferred as contributing to the sorting exhibited by the level three sediments. Subsequent soil development on these sediments increased the amounts of silts and clays thus reducing the level of sorting exhibited by the paleosol.

Additionally, throughout the excavated area the bison bone bed was in contact with the level three sediments, and occasionally, the bone was contained within those sediments. It was also observed that, where the occupation horizon was more complete, the bison bone bed was located in the bottom portion of the paleosol. This indicates that the Heron Eden site was occupied at a time near the commencement of paleosol development.

2.4 Cultural Materials and Dating

The analysis of lithic materials from a site can provide information on site function and the presence of diagnostic materials can indicate the relative age of the site. The comparison of the relative dates and the radiocarbon dates can provide additional support for the age of the site. The Heron Eden lithic collection is considered from these perspectives. The only artifacts recovered at the site are lithics and all of the lithic descriptions and identifications are taken from Linnamae and Johnson (1993). The radiocarbon dates are then presented and compared to the relative dating of the Heron Eden site based on the projectile points. A short synopsis of other Cody complex sites found on the Canadian Plains is also presented.

2.4.1 Lithic Collection and Analysis

The number of projectile points found at the Heron Eden site is relatively small. A total of 14 Paleoindian projectile points, eight complete and six fragments, were recovered (Figure 2.7). Three complete points, identified as the Scottsbluff type of the Cody complex, were found in situ in the occupation horizon. The only fragment recovered in situ is the basal half of a lanceolate shaped biface that is presumably a point preform.

The remaining five complete points, four identified as the Scottsbluff type and one as the Eden type of the Cody complex, were collected from the surface in association with the bison bone scatter. A total of five fragments were also collected from the surface. This includes two distal portions, one middle portion with shoulders, and two proximal portions, one of which is repointed without shoulders. The raw stone material used for the projectile points is diverse and includes a combination of exotic and local stone. These

include Knife River flint, silicified wood, Montana agate, jasper, chert, and possibly Beaver River sandstone.

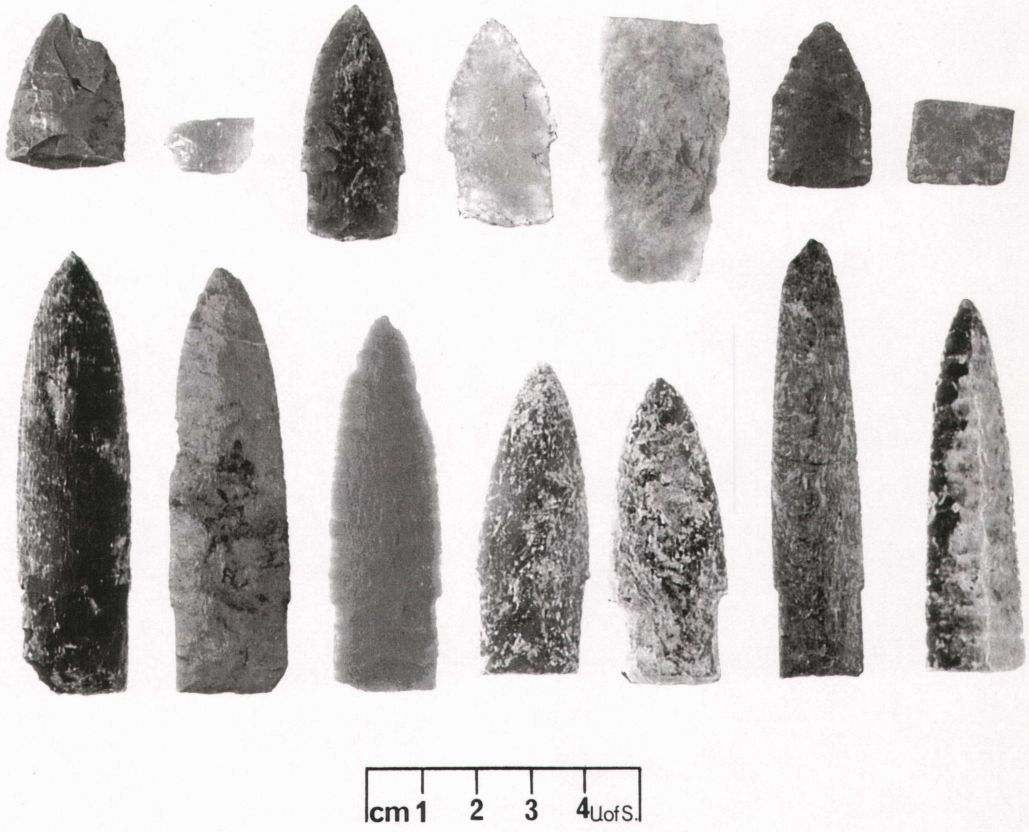


Figure 2.7 The Heron Eden site Cody complex projectile points.

The variation observed in the length of the complete specimens is suggested as representing differing function, stages of manufacture, or the reworking of broken points (Linnamae and Johnson 1993). Since use-wear analyses have not been done, the exact functions of the projectile points remains unknown. The stem size, width, thickness, and the stem/shoulder index are homogeneous for all the projectile points. The proximal area, the haft element, exhibits standard manufacture. All of the stemmed points are

finely ground or polished on the basal and stem edges (Linnamae and Johnson 1993). Seven of the complete projectile points have a transverse flaking pattern and a lenticular cross-section. These are referred to as the Scottsbluff types. One complete projectile point and one blade fragment exhibit a co-medial flaking pattern and a diamond shaped cross-section. These are referred to as the Eden type (Linnamae and Johnson 1993).

Other lithic categories include end scrapers, burin and burin spalls, other unifaces, a bifacial chopper, retouched flakes, and lithic debitage (Linnamae and Johnson 1993). There are six complete end scrapers and three proximal sections, most of which were recovered in situ in the occupation horizon. These are divided into two groups based on differential use-wear. A variety of materials, such as Knife River flint, an agate-like chalcedony, and reddish and yellowish jaspers, were used in their manufacture. One flake burin, made from a yellowish jasper, was recovered in situ in the occupation horizon. Use-wear was observed on the edge of the burin facet (Linnamae and Johnson 1993). Two primary burin spalls were also recovered, one made of Knife River flint and one of fused shale.

Three larger unifaces, manufactured from local raw material, were recovered. Two of these unifaces show use-wear on the retouched edges. A large bifacial chopper made from a quartzite cobble was found in situ in the occupation horizon. The coarse bifacial edge exhibits considerable crushing and smoothing use-wear. Six retouched flakes have been identified. Raw materials include Knife River flint, a chalcedony, a jasper, and a pinkish chert. Two exhibit unifacial retouch and two show bifacial retouch with slight use-wear. One flake, which exhibits use-wear on the end of a sharp projection, is identified as a borer/graver. The sixth flake displays slight use-wear scarring on the distal end (Linnamae and Johnson 1993).

The lithic debitage categories include core shatter and decortication flakes (approximately 13 percent of the sample), biface reduction and secondary tool shaping flakes (55 percent), and indeterminate tool shaping flakes (34 percent). These data indicate that final shaping, re-working of broken specimens, and the sharpening and rejuvenation of formed tools were the major lithic production activities exhibited by this assemblage. Very little primary tool making took place at the site. Additionally, a small amount of fire-cracked rock was recovered from the occupation horizon. Altogether, this suggests that the Heron Eden site lithic assemblage represents a special purpose activity, such as bison carcass processing, rather than a multi-activity camp site (Linnamae and Johnson 1993).

2.4.2 Radiocarbon Dating

In total, five samples of bison bone were submitted for dating to the Radiocarbon Dating Laboratory of the Saskatchewan Research Council. The results (uncalibrated) are as follows:

Sample 1 (S-3114)

Location: Excavation unit 100.00N 102.00E

Level and Depth: Paleosol, 25-30 cm depth below surface (dbs)

Material: Unburned bison bone

Date: 8930 ± 120 radiocarbon years

Sample 2 (S-3118)

Location: Excavation unit 100.00N 112.00E

Level and Depth: Paleosol, 22-30 cm dbs

Material: Unburned bison bone

Date: 10,210 ± 100 radiocarbon years

Sample 3 (S-3208)

Location: Excavation unit 100.00N 110.00E

Level and Depth: Paleosol, 27 cm dbs

Material: Unburned bison bone

Date: 8160 ± 200 radiocarbon years

Sample 4 (S-3308)

Location: Excavation unit 102.50N 111.00E

Level and Depth: Paleosol, 28 cm dbs

Material: Unburned bison bone

Date: 9210 ± 110 radiocarbon years

Sample 5 (S-3309)

Location: Excavation unit 102.50N 111.00E

Level and Depth: Paleosol, 24-27 cm dbs

Material: Unburned bison bone

Date: 8920 ± 130 radiocarbon years

Three of the radiocarbon dates cluster at approximately 9000 years before present. The two aberrant dates do not meet this cluster at the two sigma confidence level.

Frison (1991: Tables 2.2, 2.5) summarizes the radiocarbon ages generated for a number of Cody complex sites and suggests that "radiocarbon dates on the Cody Complex are two hundred or so years on both sides of 9000 years B.P." (Frison 1991:66). Three of the Heron Eden radiocarbon dates, 8930 ± 120 B.P. (S-3114), 9210 ± 110 B.P. (S-3308), and 8920 ± 130 B.P. (S-3309), can be included in this range. A fourth radiocarbon date, at 8160 ± 200 B.P. (S-3208), is considered too recent and the fifth date, at 10,210 ± 100 B.P. (S-3118), is considered too old for the accepted Cody complex dates.

2.5 Cultural Context

The majority of the Paleoindian projectile points found on the Canadian Plains are from the surface (Dyck 1983:79; Pettipas 1980:10-11). Cody complex surface finds are common throughout the grasslands and parklands of the prairie provinces (Meyer 1985:30) and can be quite extensive. A total of 77 points and fragments were collected from the surface of the Dunn site (DjNf-1) in south-central Saskatchewan over a period of 30 years (Ebell 1988:506). Based on the number and kinds of artifacts recovered, including three other bifaces, one uniface, and debitage, it is suggested that the artifacts represent a butchering area that has been destroyed by recent cultivation (Ebell 1988:510-527).

In Saskatchewan, only three Cody complex sites, Niska (DkNu-3), Napao (DkNv-2), and Heron Eden (EeOi-11), have been found to contain intact occupation deposits. These sites have all been found because cultivation and deflation exposed the paleosols which contained the occupation horizons. Both the Napao and Niska sites are found near Ponteix in southern Saskatchewan. The Fletcher site (DjOw-1) represents a single intact Cody complex bison kill-butchery site located in the southernmost part of Alberta (Forbis 1968:1). Accordingly, the Heron Eden site is the most northern Cody complex site with intact deposits to be investigated on the Canadian plains. All of these sites are located in similar environments, with a semi-arid climate, grassland vegetation, and soils formed on sandy sediments of glacial origin.

A relatively small area, consisting of 24 square meters, was excavated at the Niska site. The artifacts, from both the surface and subsurface, include seven complete and fragmentary projectile points, four Cody knives, 17 scrapers, other unifaces, core fragments, and lithic debitage. These data,

along with the presence of paint material, poorly preserved fragmented bone, burned and calcined bone, several hearths, and activity areas indicate a substantial Paleoindian camp area (Meyer 1985:8-28).

Small scale excavations of a Cody complex component were carried out at the Napao site. A number of hearths, of different types, with surrounding activity areas were uncovered. A number of artifacts, including three projectile points, one complete Scottsbluff type, one complete Eden type, and one reworked Eden type, of the Cody complex were found (Henri Liboiron, personal communication 1995). This site also indicates a Paleoindian camp area.

Varied results have been obtained from the radiocarbon dating of both sites (Morlan 1993:13). The best estimates for the occupation of the Niska site, from seven dates, are 7000 ± 185 years B.P. (S-2353) from the paleosol and 7165 ± 320 years B.P. (S-2453) from unburned bone (Meyer 1985:28) or 8475 ± 650 years B.P. (S-2510) from the paleosol (Morlan 1993:13). The best estimates for the age of the Napao site, from three dates, are 6635 ± 205 years B.P. (S-2891) and 8075 ± 230 years B.P. (S-2890), both on unburned bone (Morlan 1993:13). The older dates from both sites are similar to the youngest date from the Heron Eden site, 8160 ± 200 years B.P. (S-3208), which was previously considered to recent for the accepted age range of the Cody complex. These dating problems are presumably due to shallow burial or prior deflation episodes (Morlan 1993:13).

Excavations at the Fletcher site uncovered projectile points of the Alberta complex in association with a bison kill-butchery site (Forbis 1968:1-5). Points identified as the Scottsbluff type of the Cody complex were collected from the surface and are considered associated (Forbis 1968:5; Vickers 1986:43). The artifacts include complete and fragmentary projectile

points, spokeshaves with graver tips, scrapers, bifaces, and hammerstones. The Fletcher site radiocarbon dates are considered unreliable due to hydrological contamination (Forbis 1968:2). They range from 1675 ± 145 years B.P. (S-1081) to 7655 ± 110 years B.P. (S-1084) with one date at 4470 ± 120 years B.P. (S-1082) and a split sample dating to 4130 ± 115 years B.P. (S-1083; Quigg 1976:108) and 5960 ± 170 years B.P. (RL-560; Vickers 1986:44). These results are all considered as being too recent for the Alberta and Cody complexes.

2.6 Summary

The Great Sand Hills area is characterized by a semiarid climate. David (1972, 1982) suggests that between 10,000 and 4000 B.P. the climate was severely semiarid and the Great Sand Hills were mainly active with some periods of stability (as cited in Mollard et al. 1990: Appendix C). This environment is exceptionally climate-sensitive and a period of moister climate is required to stabilize the dunes after a destabilizing period (David 1982 as cited in Mollard et al. 1990: Appendix C). The presence of the paleosol, or the buried soil profile, at the Heron Eden site represents one such period of stability. The cultural occupation of the site, at a time similar to the commencement of paleosol development, is dated to approximately 9000 years ago. The Heron Eden site is considered to be the most reliably dated Cody complex site on the Canadian Plains.

The Heron Eden site was discovered when the cultivation and deflation of the paleosol exposed the bison bone bed. Because the initial excavations uncovered an intact portion of a Cody complex bison bone bed, the site was deemed highly significant. The Heron Eden site is one of only three Cody complex sites yet to be found in Saskatchewan with intact

deposits. It is the first in situ Cody complex kill-butchery site to be excavated in the province, the second in the prairie provinces. The Heron Eden site also represents the most northern Cody complex site yet found on the Great Plains. Hence, this analysis will provide fundamental information on Cody complex bison procurement on the Canadian Plains.

CHAPTER 3

RESEARCH METHODS

3.1 Discovery and Initial Investigations

The Heron Eden site was discovered in 1973 by avocational archaeologists Ruth Heron and Fulton Heron, who noted the presence of a bone scatter on the surface of a cultivated field (Figure 3.1). The large surface scatter yielded substantial faunal remains, identified as bison bone, and a stemmed Paleoindian projectile point identified as the Eden type of the Cody complex. The land was then seeded to grass and investigations were not possible for several years.

In 1987 cultivation resumed; the Herons returned to the specific area of the surface scatter and found other Paleoindian projectile points. Two complete points of the Scottsbluff type and one Eden type blade fragment, both types of the Cody complex, were found. They reported their find and the site was visited by archaeologists from the Royal Saskatchewan Museum of Natural History and members of the Saskatchewan Archaeological Society (SAS). A great amount of surface bone was observed but no sub-surface testing was done. The general impression was that the bone scatter represented another site which, like many others in Saskatchewan, had been destroyed by farming. At this time the majority of the surface bone was located closer to the fence line (Gil Watson, personal communication 1992) where subsequent testing in 1989 revealed no intact bone bed or paleosol.

Figure 3.1 The surface bone scatter at the Heron Eden site.

At a Regional Archaeological Volunteers meeting of the SAS, the Herons were encouraged to pursue investigation of this site through their chapter organization. The Southwest Chapter of the SAS secured funding to conduct an assessment, both surface and subsurface, of the site in the summer of 1989. The project was under the direction of Dr. Urve Linnamae from the University of Saskatchewan, with the field personnel consisting of members of the Southwest Archaeological Society (Linnamae and Cazakoff 1990). Volunteers have continuously been a large part of the Heron Eden site excavation project (Figure 3.2). Many people from both the avocational and professional archaeological community provided their time and labor in each season of excavation.

Figure 3.2 Excavations at the Heron Eden site.

Thus, the Heron Eden site archaeological project began in 1989 as an avocational project to assess the subsurface potential for a site that was thought to have been destroyed by cultivation. Sixteen square meters were excavated, uncovering a substantial bison bone bed in association with two Paleoindian projectile points identified as the Scottsbluff type of the Cody complex. Three samples of bison bone were submitted for radiocarbon dating. Since then two more radiocarbon dates were derived and three additional complete Scottsbluff type points were recovered, with one point being from the bone bed and two from the surface.

Consequently, the in situ recovery of two Cody complex projectile points within a bison bone bed, and radiocarbon dates of approximately 9000 years ago, indicated that the site was of major significance and excavations were undertaken during the next three years (Figure 3.3). The yearly

objectives were to increase the faunal and lithic sample sizes used for interpreting the content and structure of the site and for determination of the site type. The next two field projects in 1990 and 1991 resulted in the excavation of 30 square meters, bringing the total excavated sample to 46 square meters (Linnamae 1991; Linnamae and Corbeil 1991, 1992). Of these, a 32 square meter contiguous excavation block was located in the eastern, more productive area of the site. Another field season was spent at the site in the summer of 1992 attempting to recover as much of the intact occupation as possible (Linnamae and Corbeil 1993). Thirty-six square meters were added to the eastern contiguous excavation block (Figure 3.3) for a site total of 82 square meters.

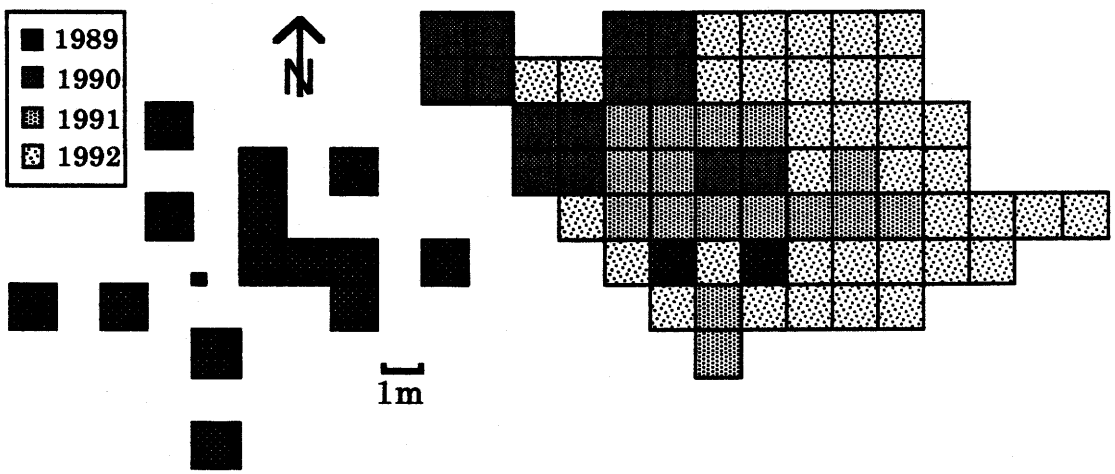


Figure 3.3 Location of the Heron Eden site excavation units by year.

Although the yearly excavation projects resulted in substantial recoveries from the site, the exact boundaries of the paleosol were unknown. The excavations indicated that a portion of the bone bed remained intact. Thus, an assessment (Figure 3.4) was undertaken in 1993 to determine the margins of the bone bed and the extent of the paleosol (Corbeil 1994).

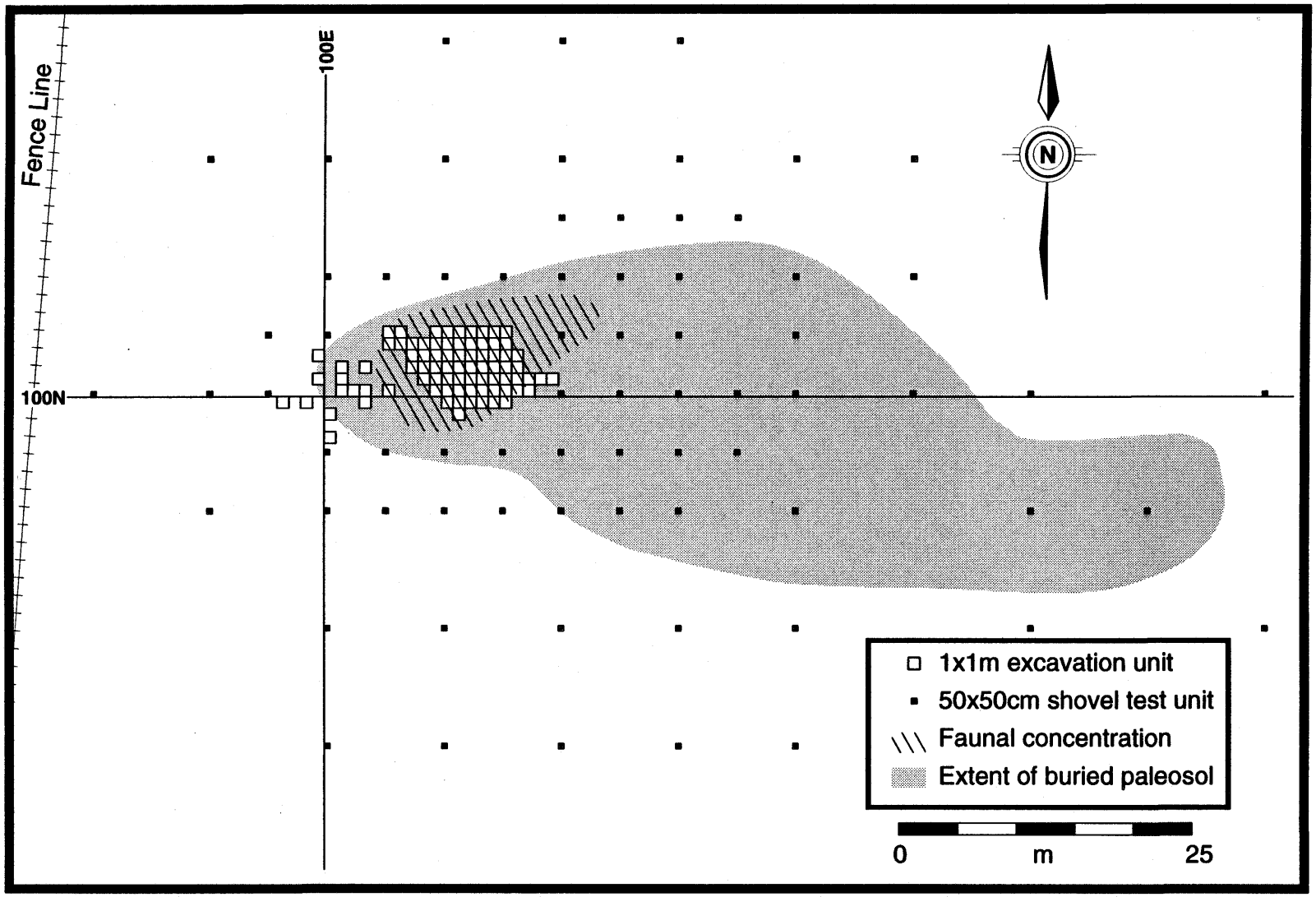


Figure 3.4 Location of the Heron Eden excavations in relation to the bison bone bed and paleosol.

The only original bone bed boundary was located in the eastern margin of the excavation block. To the north, west, and south a combination of cultivation and sedimentary deflation has removed the paleosol and associated faunal material. With only one intact border an estimate of the original extent of the bone bed is not possible.

Subsequently in 1994 and 1995, the Heritage Branch, Government of Saskatchewan, together with the principal investigators and the landowner, put together a short term preservation plan that will stabilize the surface of the site and halt further cultivation. With funding from the Heritage Foundation, Government of Saskatchewan and cooperation from the landowner, the Heron Eden site and associated paleosol have been fenced off and seeded into grass.

3.2 Excavation Methods

All excavations were completed utilizing the original 1989 site datum. The original datum was placed at a high point on the approximate center of a small knoll. This point was designated as 0North/South 0West/East and the excavation unit provenience was assigned by the southeastern corner. The first two seasons of excavations utilized this unit designation scheme. In order to locate all of the excavated units in one directional quadrant to facilitate computer data handling, the original datum point provenience was changed and designated 100N 100E with the excavation unit provenience assigned by the southwestern corner.

This 100N 100E datum was buried below the surface after initial excavations uncovered the intact bone bed. Two accessory datums were placed along the fence line to facilitate finding the primary datum when necessary. The provenience of these accessory datums were then in turn

related to the northwest corner of the municipal land section. Each year a new grid was established from the site datum, because ongoing farm activities required the removal of all unit designation pins each time a project was completed. Therefore, the excavation units were always aligned to the coordinate system set up at the beginning of the excavation program. Some variation occurred but was slight and considered to have a negligible effect on future analyses. Each unit had a designated subdatum from which all measurements were taken. The elevation of the subdatums were taken relative to the site datum so that all depth measurements were comparable.

Excavation of each one square meter unit at the Heron Eden site followed natural levels. The sedimentary matrix was passed through 6 mm mesh. The plowzone, extending from the surface to the bottom of the cultivation horizon, was excavated as level one. Since the plowzone was mixed due to cultivation, each one meter unit was collectively bagged.

In all cases, the top of the paleosol was in direct contact with the bottom of the plowzone. Subsequent excavation levels were 10 cm in depth or until the bottom of the paleosol was reached. The paleosol was never more than two exposures thick. Each paleosol level was excavated by quadrants with significant materials left in place (Figure 3.5). Once the bone was exposed, each unit was photographed and mapped (planviewed) using a 20 cm grid system. After vertical provenience was taken, each artifact was given a field number and removed. A fine screen sample was systematically collected from one quadrant of each unit. Although some artifact washing took place in the field camp, the majority of the artifacts were transported to the University of Saskatchewan to be cleaned and catalogued. After each unit was excavated, select wall profiles were photographed and drawn in a manner to interconnect the profiles across the site. In addition, many

sediment samples were collected from the paleosol and underlying sterile sediments.

Figure 3.5 Photograph of the ongoing excavations. The excavation units are in various stages of completeness.

The excavation procedures differed slightly in the first season of excavation. Due to time constraints in 1989, only excavation units with substantial faunal remains were photographed and drawn. Bone fragments from the coarse screenings were collected by the square meter. Representative profiles were drawn of four units and several fine screen samples were collected.

3.3 Laboratory Procedures

The majority of the Heron Eden site collection was transported to the University of Saskatchewan, where it was cleaned and sorted. Some of the washing was completed at the archaeological and paleoenvironmental laboratory at the Wanuskewin Heritage Park by student volunteers. If a fragment bag contained faunal materials identifiable to element or element portion, it was removed and catalogued separately. When an unidentifiable fragment bag for a square meter or quadrant provenience unit contained an extreme number of fragments, a sample was counted and weighed, and by comparison to the total weight, an estimate count was taken.

The faunal material was catalogued using MacADEM 10.6, an archaeological data entry and management program designed for the Macintosh (Gibson 1991). The basis of the coding system is the identification of element and element portion. The condition of the bone, (complete, nearly complete, or fragment), is recorded to allow for the effects of fragmentation. Other observations made of each specimen, when possible, include the side of the specimen (left, right, axial, indeterminate), an age estimate (fused, unfused, immature, foetal, indeterminate), and the taxon. Cultural and natural modifications can also be recorded. Specimen counts and weights, in grams, were recorded for all catalogued entries.

Tentative identifications were either confirmed or refuted through comparisons with bison skeletal material in the University of Saskatchewan comparative collection. Artifacts were then secured in plastic bags, along with a printed label containing provenience and descriptive information, and packed in storage boxes.

3.3 Analytical Procedures

Various analyses involving the herd structure and the abundance of skeletal parts at the Heron Eden site were carried out. Analyses involving the measurement of carpals and tarsals, metapodials, and long bones were done to determine the bison herd composition. A detailed study of the lower dentition was completed to determine the population structure and seasonality of site use. An examination of attritional processes was carried out to relate to the structure and content of the bone bed. The presence and absence of skeletal part frequencies were compared to indices of economic utility and bone mineral density to infer the agents of attrition. All information was then considered to assess the degree to which cultural and natural processes have affected the faunal assemblage.

While the Heron Eden site faunal material was considered as a single assemblage for some analyses it is divided by level for others. As well, in these analyses, several quantitative measures are used and the basic terminology is based on definitions in the literature. A thorough summary of zooarchaeological quantitative units and their definitions has been compiled by Lyman (1994b). Others (Brewer 1992; Grayson 1979, 1984; Klein and Cruz-Uribe 1984; Lyman 1994a; Ringrose 1993) present definitions of some principal quantitative units and discuss the various strengths and weaknesses of the different quantitative measures.

Many references are made to terms such as specimens and element. Grayson (1984:16) following Shotwell (1955,1958) defines a faunal *specimen* as "a bone or tooth, or fragment thereof, ... while an *element* is a single complete bone or tooth in the skeleton of an animal". Thus, a complete radius is both an element and a specimen while a proximal radius is a specimen. These definitions are used in this thesis.

A faunal assemblage refers to the recovered set of faunal specimens from a given cultural or geological context, in which the defining context has been defined by the analyst (Grayson 1984:17; Brewer 1992:195). Either all the faunal material from a single site can be referred to as a single assemblage, or it can be divided into a series of assemblages based on the analyst's goals. Aggregation is the process of defining the boundaries for a given faunal assemblage (Grayson 1984:17). Therefore, the Heron Eden site *faunal assemblage* refers to all of the faunal specimens recovered from the excavations which occurred between 1989 and 1992. The *plowzone aggregate* refers to the portion of the faunal assemblage recovered from the plowzone. Similarly, the *paleosol aggregate* refers to the portion of the faunal assemblage recovered from the paleosol (also called the occupation horizon). Thus, the faunal assemblage is composed of the plowzone and paleosol faunal aggregate samples.

The principal quantification measures used in this thesis include the number of identified specimens (NISP), the minimum number of individuals (MNI), the minimum number of elements (MNE), and the minimum animal units (MAU). The definition of the NISP used in this thesis is taken from Brink and Dawe (1989). *NISP* refers to all the bones which have been identified as to a specific element or to a general class of elements, such as long bone fragments or indeterminate tooth fragment (Brink and Dawe 1989:81). This does not include the indeterminate bone fragments catalogued as unidentifiable faunal material. In this thesis a modified NISP count is used when the distribution of the faunal material is being considered. Indeterminate tooth fragments are more easily identified, even when highly comminuted, than bone and tend to inflate the NISP counts.

Therefore, the *modified NISP* refers to the NISP less the number of indeterminate tooth fragments.

The MNI is another abundance count that is frequently used. The MNI is simply the number of individual animals necessary to account for all identified specimens (Grayson 1979, 1984). The *MNI* utilized here is the number of individual animals necessary to account for all identified specimens, taking the left or right side into account.

The MNE used in this thesis is taken from Lyman (1994a). The *MNE* counts the minimum number of elements needed to account for the specimens observed (Lyman 1994a:510). MNE can refer to complete or whole elements (Bunn 1989:307), to proximal and distal parts of elements (Todd and Rapson 1988:308), and to element portions or anatomical features or zones (Morlan 1994b:799). An element portion is a discrete anatomical feature or a defined anatomical zone for a particular element (Morlan 1994b:799). Thus, an anatomical *element* is made up of *parts* which are subsequently made up of *portions*. For example, a complete radius has a proximal and distal part. The proximal part is made up of the lateral and medial tuberosities (portions). If the lateral tuberosity has the greater portion MNE count, then it is considered the proximal part count. If the proximal part count is greater than the distal, it is considered the complete element MNE. Thus, in this manner, the Heron Eden site MNE counts were all derived from portion counts (see Appendix A).

The MAU counts the minimum number of animal units necessary to account for the specimens observed (Lyman 1994a:510). The *MAU*, as used in this thesis, is calculated by dividing the MNE by the number of that element in one skeleton. The MAU's are standardized as %MAU, percentages of the highest MAU. This was originally defined by Binford

(1978:70) as MNI, but changed by Binford (1984:51 as cited in Lyman 1994b:42-43).

The percentage completeness (*%CN*) is the percentage completeness of individual elements (Morlan 1994b:805). This measure examines the fragmentation of select elements based on a predetermined number of portions. This differs from the percentage complete (*% Complete*) measure, the percentage of complete elements (Todd and Rapson 1988:309) which measures differential element destruction and/or removal. This method is based on the analysis of long bones. The percentage difference (*% Difference*) is the percentage difference between proximal and distal articular ends of long bones (Todd and Rapson 1988:309). This measure is for recognizing patterns of differential destruction of long bone proximal and distal ends. It is used to identify long bones that have one end preferentially destroyed or removed. All three measures are used in this study.

CHAPTER 4

THE HERON EDEN SITE BISON ASSEMBLAGE

4.1 Introduction

The Heron Eden faunal assemblage is composed primarily of bison bone. There are no complete or partially articulated skeletons. A few element segments are considered to be associated, based on successive elements being found in near proximity. However, the bone bed is generally characterized by a mixed scatter of complete and fragmentary specimens.

In this section, after a brief discussion of the non-bison remains, the fragmentation and distribution of faunal specimens are examined to indicate the general condition of the bone bed. The composition of the assemblage is then examined to reconstruct the bison herd population dynamics. Particular attention is given to the determination of gender and age groupings for inferences concerning bison herd composition, species identification, population structure, and the seasonality of site use.

4.2 Non-bison Remains

Eleven elements are identified as non-bison, one recovered with point provenience and 10 from the bulk 6 mm screenings. The format for the systematic descriptions follows Walker (1992). All Canadian geographic distributions are taken from Banfield (1987). The presence of contemporary taxa in the Great Sand Hills region is confirmed by Epp and Waker (1980:82-84) and Graham et al. (1987:429-431). NISP denotes the "number of identified specimens".

Class Mammalia, Order Rodentia, Family Geomyidae, *Thomomys talpoides* [Northern Pocket Gopher]. NISP = 3: left mandible (EeOi-11:353), left humerus (429), right tibia (430).

Discussion: These specimens, which could represent one individual, are considered to be associated based on their recovery in one bulk provenience group. The relative completeness of the specimens and the lack of weathering, other than superficial rootlet etching, or other modification (following Morlan's 1994a:137 rodent bone modification variables) suggests they may be self-intruded into the site. The northern pocket gopher is found across the southern portions of the Canadian prairie provinces.

Order Rodentia, Family Sciuridae, *Spermophilus richardsonii* [Richardson's Ground Squirrel]. NISP = 5: cranium (EeOi-11:6624), right mandibles (1228, 1693), right humerus (8553), right innominate (2637).

Discussion: These specimens were found scattered throughout the excavation area. At minimum, they could represent two individuals. Other than rootlet etching, they are relatively complete and unweathered and can be considered as self-intruded. Richardson's ground squirrel is also found across the southern portions of the Canadian prairie province.

Order Carnivora, Family Canidae, *Canis lupus* [Gray Wolf]. NISP = 2: left second metacarpal (EeOi-11:6157), left third metacarpal (6158).

Discussion: These specimens have been assigned to species based on size. The two metacarpals (Figure 4.1) are slightly larger than the modern gray wolf specimens in the University of Saskatchewan comparative collections. The two specimens could represent one individual.

The specimens are considered non-intrusive because their weathering and surface texture is comparable to the rest of the faunal assemblage. This taxon is also found associated with other kill sites, such as the Agate Basin

site (Walker 1982:291) and the Hawken site (Frison et al. 1976:53). The gray wolf was historically spread throughout much of North America but has been largely exterminated in the southern portions of the Canadian prairie provinces.

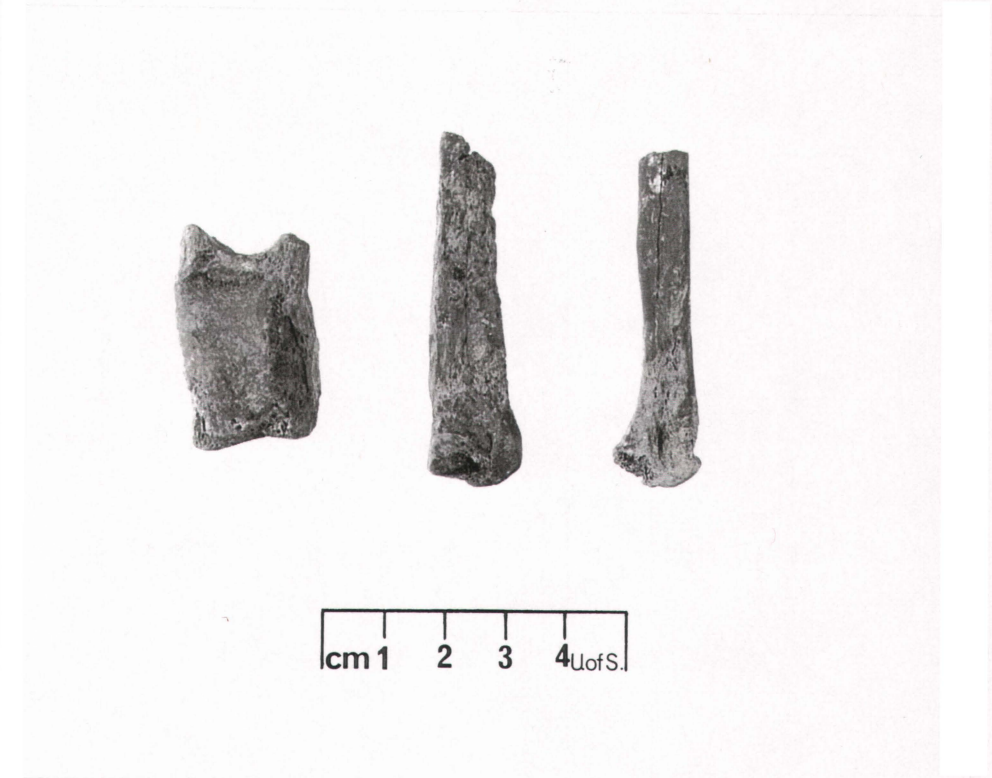


Figure 4.1 The non-bison remains considered contemporaneous with the bison assemblage; one Pronghorn astragalus and two wolf metacarpals.

Order Artiodactyla, Family Antilocapridae, *Antilocapra americana* [Pronghorn]. NISP = 1: left astragalus (EeOi-11:5018).

Discussion: Due to similar weathering and bone texture, this element is considered to be contemporaneous with the bison bone bed (Figure 4.1). Pronghorn are commonly found at kill sites and often display evidence of butchering. Examples of these sites include the Horner site (Walker 1987:335), the Casper site (Wilson 1974:131), the Agate Basin site (Walker

1982:295), and the Hawken site (Frison et al. 1976:53). This specimen does not exhibit any form of cultural modification.

In western North America, Pronghorn formerly ranged over much of the treeless prairie region. In Canada, they are now restricted to the south corners of Saskatchewan and Alberta.

4.3 Bison Element Counts

A total of 220,164 bone specimens, with a weight of 453.9 kilograms, was recovered from the Heron Eden excavations (Table 4.1). This does not include the 11 non-bison specimens previously discussed. Nearly 90% (N = 193,017) of the assemblage consists of unidentifiable fragments, but they only make up 29% (N = 131.5 kg) of the total weight. This indicates the great degree of bone fragmentation present in the faunal assemblage. The remainder of the bone specimens provide a bison NISP of 22,898. Another category with high counts, the other axial group, which contains rib shaft fragments, indeterminate vertebral fragments, and indeterminate tooth fragments, also indicates the extent of bone fragmentation.

Table 4.2 presents the bison NISP's by element for the plowzone and paleosol aggregate samples that together make up the total faunal assemblage. MNE, MAU, and MNI denote "minimum number of elements," "minimal animal units," and minimum number of individuals" respectively. The total MNE's for each element are presented along with the total MAU and MNI they represent. An MNI of 37 animals and a MAU of 36 units is calculated using mandibular third molar counts. The radial carpal, carpal 4, and tarsal 2+3 all have a MNI of 35. The maximum bone MAU is 32.5 for carpal 4.

Table 4.1 The Heron Eden site faunal assemblage totals*.

Element group	Bison NISP	Specimen frequency	Percent frequency	Specimen weight	Percent weight
Axial elements	2646	3778	1.7%	84.5	18.6%
Forelimb elements	1141	1554	0.7%	70.6	15.6%
Hindlimb elements	982	1338	0.6%	69.6	15.3%
Other appendicular	1899	3403	1.5%	55.9	12.3%
Other axial	16230	17074	7.8%	41.8	9.2%
Bone fragments	-	193017	87.7%	131.5	29.0%
Totals	22898	220164		453.9	

*Does not include the 11 identified non-bison specimens.

Table 4.2 Bison element counts from the Heron Eden site.

Group Element	Plowzone NISP	Paleosol NISP	Total NISP	Total MNE	Total MAU	MNI (side)
Axial elements						
Cranium -petrous*	46	312	358	43	21.5	23
Mandible -third molar*	95	786	881	72	36.0	37
Hyoid	1	27	28	11	5.5	6
Sternum	0	2	2	2	0.4	1
Rib head	5	141	146	146	73.0	6
Atlas	3	43	46	17	17	17
Axis	3	41	44	19	19	19
Cervical	26	280	306	62	12.4	13
Thoracic	23	421	444	131	9.4	10
Lumbar	11	294	305	91	18.2	19
Sacral	0	42	42	28	5.6	15
Caudal	2	42	44	42	4.2	5
Forelimb						
Scapula	17	226	243	46	23.0	28
Humerus	11	152	163	41	20.5	22
Radius	13	113	126	40	20.0	22
Ulna	17	128	145	42	21.0	24

Continued

Table 4.2 (continued) Bison element counts from the Heron Eden site.

Group Element	Plowzone NISP	Paleosol NISP	Total NISP	Total MNE	Total MAU	MNI (side)
Forelimb (continued)						
Radial carpal	13	51	64	62	31.0	35
Internal carpal	8	51	59	58	29.0	34
Ulnar carpal	6	48	54	54	27.0	30
Accessory carpal	5	35	40	40	20.0	22
Carpal 2+3	11	46	57	57	28.5	29
Carpal 4	9	57	66	65	32.5	35
Metacarpal, 5th	5	31	36	34	17.0	18
Metacarpal	11	77	88	44	22.0	22
Hindlimb						
Innominate	9	135	144	42	21.0	23
Femur	9	141	150	42	21.0	21
Patella	3	31	34	34	17.0	18
Tibia	14	177	191	37	18.5	20
Lateral malleolus	7	42	49	49	24.5	26
Astragalus	10	47	57	50	25.0	27
Calcaneus	12	76	88	49	24.5	27
Tarsal C+4	18	57	75	61	30.5	33
Tarsal 2+3	6	57	63	63	31.5	35
Tarsal 1	2	17	19	19	9.5	10
Metatarsal, 2nd	4	18	22	22	11.0	11
Metatarsal	13	77	90	41	20.5	22
Other appendicular						
First phalanx	45	238	283	232	29.0	29
Second phalanx	28	200	228	218	27.3	28
Third phalanx	9	180	189	179	22.4	23
Sesamoid, prox-med.	25	135	160	160	20.0	20
Sesamoid, prox-lat.	24	125	149	149	18.6	19
Sesamoid, distal	6	79	85	85	10.6	11
Sesamoid, indt.	2	9	11	-	-	-
Metapodial	20	91	111	-	-	-
Indt. long bone	71	612	683	-	-	-
Other axial						
Vertebra, indt.	43	387	430	-	-	-
Rib body frag.	760	5654	6414	-	-	-
Tooth, indt.	3934	5452	9386	-	-	-
Totals	5415	17483	22898			

* MNE, MAU, and MNI counts based on portion indicated.

4.4 Distribution of Faunal Remains

As previously noted, the bulk of the assemblage is highly weathered and fragmented. In order to include the unidentified fragments in the examination of bone distribution, bone weights are used. Figure 4.2 presents the concentration of bone using the total weight per square meter. An area of higher concentration is observed in the central portion of the contiguous excavation block, around which there is a general decrease in bone weight by square meter. Two intermittent areas of higher concentration are noted to the west. To further investigate the distribution of faunal remains a modified NISP count per square meter is utilized.

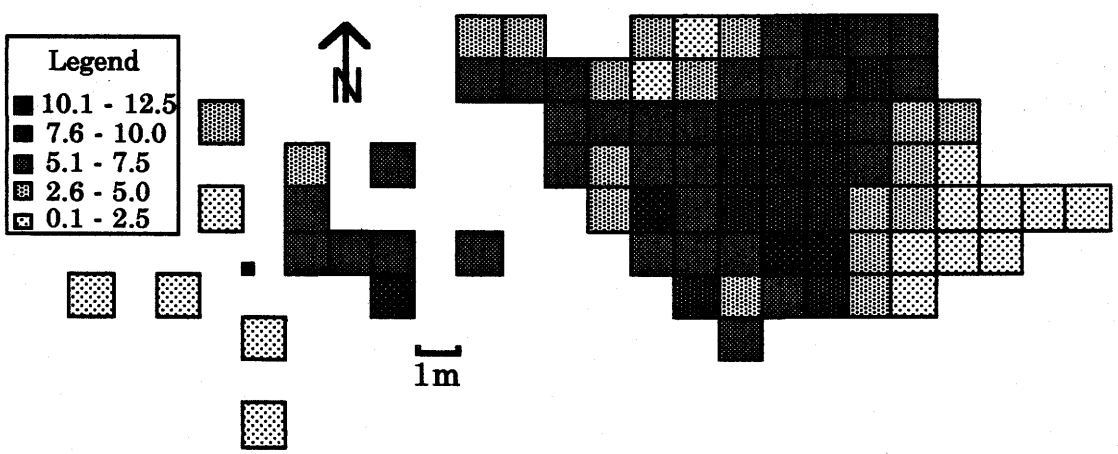


Figure 4.2 Faunal assemblage concentration using total bone weight, in kilograms, per square meter.

NISP counts include all the specimens identified by specific element or to a general class of elements (see Chapter 3). Thus, all of the fragments listed as the other axial group (Table 4.2) are included. Indeterminate tooth fragments make up 83.0% (N = 3934) of this category inflating the NISP counts per square meter. Thus, a modified NISP count, the NISP less the indeterminate tooth fragments per square meter, is utilized.

Figure 4.3 shows that the modified NISP concentration for the assemblage is comparable to the total bone weight distribution in Figure 4.2. The modified NISP frequencies uniformly decrease from a central area of concentration in the contiguous excavation block. Slight increases in frequency are noted to the west and northwest.

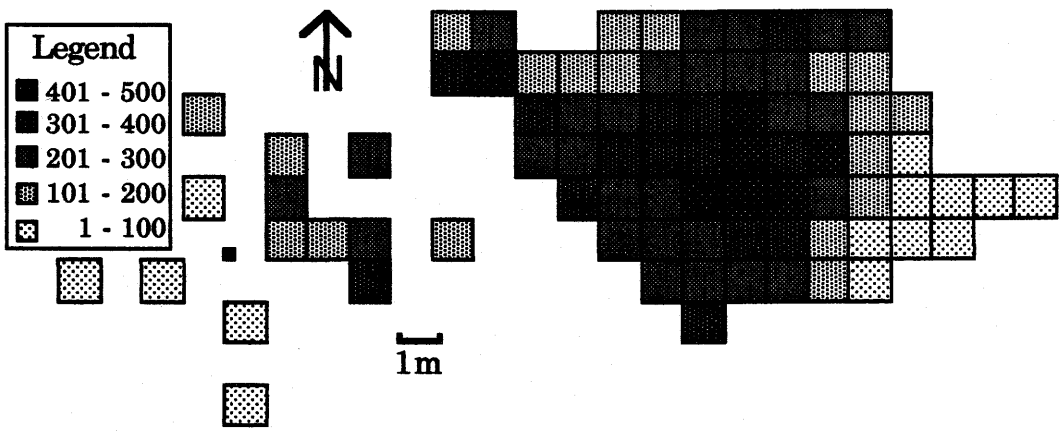


Figure 4.3 Faunal assemblage concentration using modified NISP per square meter.

There is a lack of element articulations and areas of special concentration, such as crania and mandibles, bone piles, butchering areas, and hearths. There is a lack of patterning in the distribution of lithic specimens (Urve Linnamae, personal communication 1995). Small concentrations of darkly stained soil are noted in five areas of the contiguous excavation block, but it is difficult to infer their source or function due to the lack of associated ash and/or burned bone. A small amount of the faunal assemblage is burned (N = 3877, 1.8% of the total assemblage) and consists mainly of indeterminate bone and tooth fragments. When their concentration per square meter is considered, the burned material is evenly distributed across the excavation area.

The distribution of axial, forelimb, and hindlimb frequencies were investigated for possible concentrations. Figures 4.4 to 4.6 present the relevant specimen frequencies per square meter. These element group densities are similar to that described for the modified NISP distributions (Figure 4.3). In all cases, the frequencies tend to decrease from an area of central concentration. The similar bone density concentrations indicate that there are no variations in the distribution of faunal material.

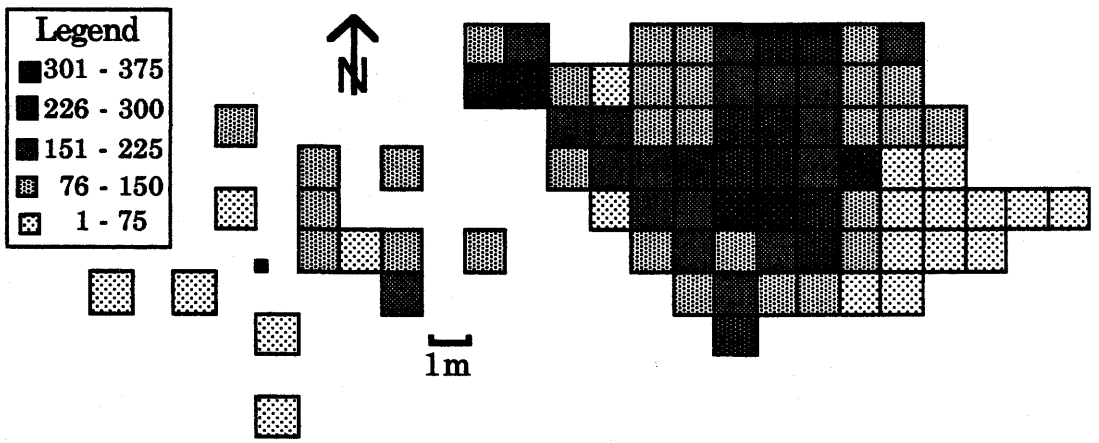


Figure 4.4 Axial concentration using modified NISP per square meter.

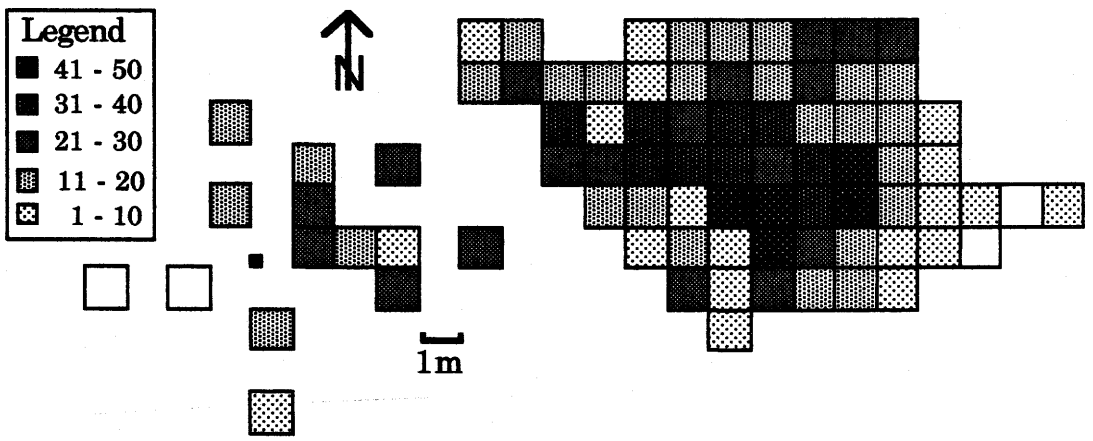


Figure 4.5 Forelimb concentration using modified NISP per square meter.

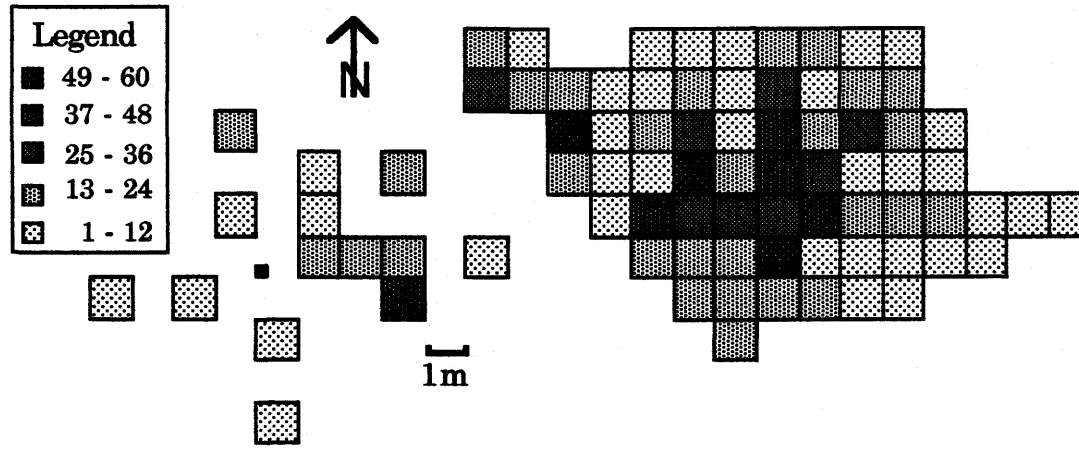


Figure 4.6 Hindlimb concentration using modified NISP per square meter.

4.5 Gender Determination

Many methods can be employed to determine gender ratios in archaeological bison populations. These are based on the assumption that the sexual dimorphism demonstrated by modern bison was present in past populations. On this basis, gender determinations, from differences in element size, can be applied to bison materials found in archaeological contexts (Duffield 1973, Speth 1983, and Todd 1987a).

Weathering and fragmentation at the Heron Eden site limits the use of this approach to those skeletal elements better represented. For example, cranial elements, which are considered good indicators of sex, are highly fragmented and not well represented. Accordingly, the more compact appendicular elements form the basis for this analysis.

Where possible, measurements are taken on refitted elements. This is done when the bone is fragmented due to modern breakage and can be reconstructed to give accurate results. Also, in some cases, estimates are made on broken or weathered specimens. These are both clearly indicated when taken (see Appendix A).

4.5.1 Carpals and Tarsals

The most common and well preserved appendicular elements are the smaller and more dense carpal and tarsal bones. Apart from the calcaneus, carpals and tarsals are generally ignored for gender determinations because it is frequently not possible to distinguish between immature and mature individuals (Morlan 1991:215). Accordingly, differences in size may reflect maturity rather than gender. However, the observations of bimodality in bivariate plots can still be used to infer the presence of a male group that is larger in size than a mixed female and immature group (Morlan 1992:203).

The methods used for the study of carpals and tarsals follow those set forth by Morlan (1991). Five of six carpal bones were measured, the accessory carpal being too variable in shape. Four of five tarsal bones and the lateral malleolus were also measured, tarsal 1 being variable and difficult to orient. Measurements consistently difficult to replicate are considered unreliable and were not taken. For each of the carpals and tarsals all possible combinations of measurements were plotted and those which display the best or most representative separation are presented. After plotting, the mean and standard deviation (s.d.) were figured for the male and female/immature group measurements. Specimens with single measurements were then assigned gender based on 2.0 s.d. Additionally, it was noted during analysis that many of the smaller carpals and tarsals were not measurable due to increased weathering. This presumably results in the under-representation of female and immature specimens.

The calcanei were considered individually since these elements can be separated by epiphyseal fusion into mature and immature groups. A bivariate plot of the length of the talar facet and the length of the tarsal C+4 facet provides good separation between three mature females and nine

mature males (Figure 4.7). Two immature specimens fall into the range of the male group and two are between the female and male groups obscuring bimodality. All of the immature specimens and one specimen with indeterminate maturity can be considered male as they are either outside the female range approaching the male grouping or contained within that latter grouping. At 2.0 s.d., a total of six specimens occur in the female/immature group, 22 specimens in the male group, and 21 specimens are of indeterminate gender (Table 4.3).

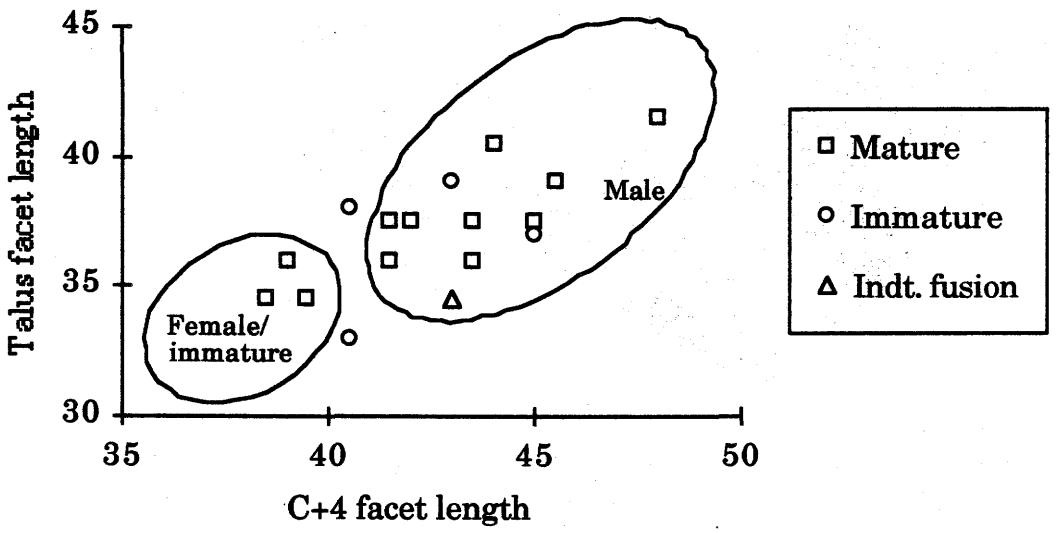


Figure 4.7 Calcaneus bivariate plot considering epiphyseal fusion.

Thus, in regard to these observations, a clustering of higher values in a bivariate plot, without reference to maturity, is considered to represent mature males and immature males large enough to fall into the male range. Accordingly, the clustering of smaller values is deemed to contain mature females and immature specimens of unknown gender.

Table 4.3 Carpal and tarsal gender determinations.

Carpal/Tarsal	MNE	Measure*	Bivariate plots F/Im	Male	Indt †	2.0 Standard deviation F/Im	Male	Indt †
Calcaneus	49	Tal/C4	3	14	32	6	22	21
Carpals								
Radial carpal	62	Wd/Lg	3	32	27	3	45	14
Internal carpal	58	Dp/Lg	4	34	20	6	39	13
Ulnar carpal	54	Dp/aLg	4	34	16	5	39	10
Carpal 2+3	57	Dp/Wd	3	34	20	3	40	14
Carpal 4	65	Dp/Wd	2	38	25	2	41	22
Mean			3.2	34.4	21.6	3.8	40.8	14.6
Percent			5.4%	58.1%	36.5%	6.4%	68.9%	24.7%
Tarsals								
Tarsal 2+3	63	Dp/Wd	5	34	24	7	37	19
Tarsal C+4	61	Dp/Wd	7	33	21	7	33	21
Astragalus	50	dWd/mLg	4	33	13	4	36	10
Lat. malleolus	49	Lg/Dp	7	19	23	7	31	11
Mean			5.8	29.8	20.3	6.3	34.3	15.3
Percent			10.3%	53.4%	36.3%	11.2%	61.4%	27.4%
Total								
Count			42	305	221	50	363	155
Mean			4.2	30.5	22.1	5	36.3	15.5
Percent			7.4%	53.7%	38.9%	8.8%	63.9%	27.3%

Abbreviations: F/Im = female/immature and Indt = indeterminate.
* Measures as cited in Morlan (1991); abbreviations: Tal = talar facet, C4 = central/fourth facet, Wd = width, Lg = length, Dp = depth, aLg = anterior length, dWd = distal width, and mLg = medial length.
† Indeterminate includes both elements which were measured and could not be assigned to a gender group and elements which were not measurable.

All of the carpal bivariate plots exhibit distinct groupings and consistent results. Figure 4.8 exhibits the plot of carpal 2+3. The large group of higher values represents 34 male specimens and the limited group of smaller values indicates three female/immature specimens. Altogether,

approximately 5.4% (N = 16, mean = 3.2) of the carpals are interpreted as being female/immatures, 58.1% (N = 172, mean = 34.4) as being males, and 36.5% (N = 108, mean = 21.6) as indeterminate gender (Table 4.3). At 2.0 s.d. the percentiles increase slightly to 6.4% female/immatures and 68.9% males.

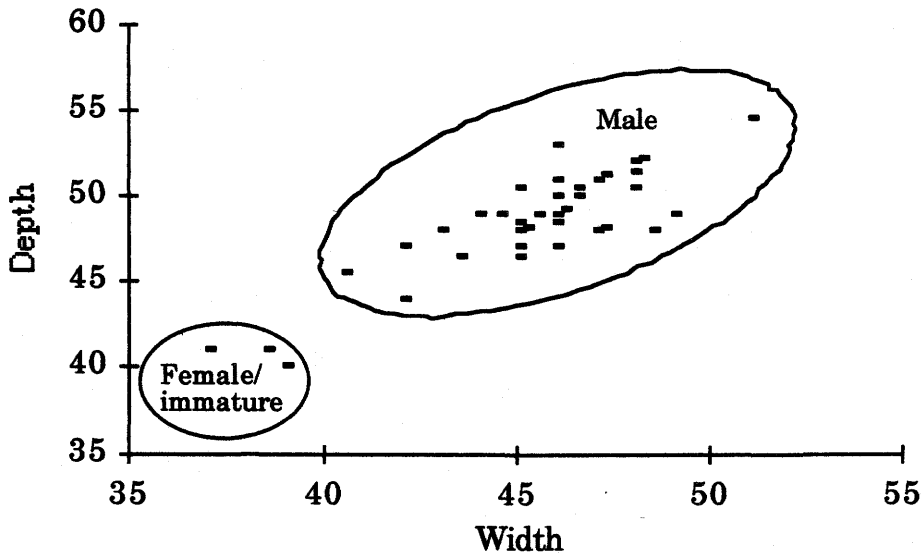


Figure 4.8 Carpal 2+3 bivariate plot

The results of the tarsal measurement plots, excluding the calcaneus and including the lateral malleolus, are also consistent but with less distinct groupings. Figure 4.9 exhibits the bimodality of tarsal 2+3, having 34 male specimens, 5 female and immature specimens, and one indeterminate specimen which occurs outside both ranges. Altogether, approximately 10.3% (N = 23, mean = 5.8) of the tarsals are interpreted as being female/immatures, 53.4% (N = 119, mean = 29.8) as being males, and 36.3% (N = 81, mean = 20.3) as indeterminate gender (Table 4.3). At 2.0 s.d. the percentiles increase to 11.2% female/ immatures and 61.4% males.

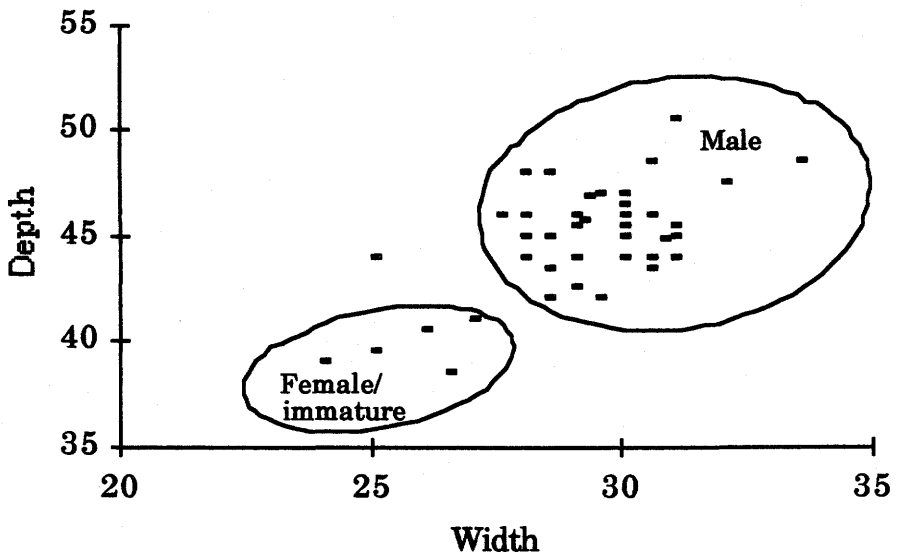


Figure 4.9 Tarsal 2+3 bivariate plot.

When the results from the bivariate plots are combined (Table 4.3), 7.4% (mean = 4.2) are interpreted as being female/immatures, 53.7% (mean = 30.5) as being males, and 38.9% (mean = 22.1) as indeterminate gender. At 2.0 s.d. the percentiles increase slightly to 8.8% (mean = 5.0) female/ immatures and 63.9% (mean = 36.3) males.

Select carpal measurements from the Heron Eden site are compared with those summarized by Morlan (1992) for three 6000 year old bison samples from Saskatchewan (Table 4.4). Overall, the Heron Eden female/immature measurements and means are similar to those of the Gowen sites and are generally smaller than those of the Norby site. The Heron Eden male measurements and means are generally larger than those for all three sites.

An exception is the ulnar carpal depth. This measurement was difficult to replicate consistently in the fashion described by Morlan (1991:221), "Depth is measured from the relatively flat accessory carpal facet

Table 4.4 Select bison carpal measurements from the Heron Eden site compared with three 6000 year old bison samples from Saskatchewan.*

		Female/immature					Mature males			
Sample	N	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.
Radial carpal length										
Heron Eden	3	30.0	1.2	29.0	31.0	32	36.6	2.1	33.0	41.0
Gowen 1	5	31.6	1.1	30.5	33.3	2	34.9	-	33.3	36.5
Gowen 2	10	30.4	1.8	27.4	33.5	5	34.1	1.3	32.0	35.2
Norby	5	32.5	1.5	30.0	34.0	33	36.0	1.3	33.8	38.2
Intermediate carpal depth										
Heron Eden	4	43.7	1.4	42.0	45.5	34	54.3	2.7	48.5	59.0
Gowen 1	1	45.4	-	-	-	1	50.3	-	-	-
Gowen 2	11	44.4	2.0	41.6	47.9	2	53.0	-	52.3	53.7
Norby	2	45.5	-	45.0	46.0	25	53.7	2.1	51.0	57.2
Ulnar carpal depth										
Heron Eden	4	38.3	1.3	37.0	40.0	34	44.6	1.7	40.5	48.0
Gowen 1	3	36.7	1.6	35.0	38.2	1	47.8	-	-	-
Gowen 2	12	37.6	1.8	34.9	39.8	4	43.0	1.4	41.5	44.9
Norby	4	39.7	1.2	38.0	41.0	26	45.5	2.5	41.2	49.5
Distal carpal 2+3 width										
Heron Eden	3	40.7	0.6	40.0	41.0	34	49.1	2.2	44.0	54.5
Gowen 1	5	39.3	0.9	38.0	40.2	0	-	-	-	-
Gowen 2	8	39.7	1.7	37.4	42.1	7	46.6	2.5	44.0	51.1
Norby	7	42.5	1.6	40.0	44.5	24	47.4	1.7	44.1	50.8
Distal carpal 2+3 depth										
Heron Eden	3	38.2	1.0	37.0	39.0	34	45.9	2.1	40.5	51.0
Gowen 1	5	36.4	2.2	34.0	39.9	0	-	-	-	-
Gowen 2	8	37.3	1.4	35.4	39.3	7	43.4	1.5	41.0	45.7
Norby	7	38.6	1.0	37.3	40.2	24	44.0	1.8	40.5	48.1
Distal carpal 4 width										
Heron Eden	2	30.0	0.7	29.5	30.5	38	37.7	2.1	33.5	41.0
Gowen 1	7	29.5	1.0	28.0	30.6	1	38.7	-	-	-
Gowen 2	9	29.7	1.5	28.0	31.7	4	33.7	1.2	32.3	35.2
Norby	4	31.8	2.5	29.0	35.0	31	35.6	1.7	31.5	39.6
Distal carpal 4 depth										
Heron Eden	2	34.5	0.7	34.0	35.0	38	41.8	2.1	37.0	46.0
Gowen 1	7	32.4	2.3	28.2	34.8	1	43.2	-	-	-
Gowen 2	9	33.5	1.6	31.6	35.5	4	39.3	0.9	38.5	40.6
Norby	4	35.4	0.7	34.6	36.1	31	40.4	1.7	37.0	43.0

* Gowen data from Morlan (1992); Norby data from Morlan (1992 from Zurburg 1991).

to the anterior surface". In the present study, an altered form of the measurement was found to be consistently replicable. This measurement is taken from the center of the relatively flat accessory carpal facet to the center of the relatively flat intermediate carpal facet. Consequently, the Heron Eden ulnar depth measurements are consistently smaller than the comparable measurement taken by Morlan (1992).

At first glance the Heron Eden data suggest domination by a male, or bull herd. The male group measurements, as expected, due to differences in the age of the sites, are consistently larger than those of the Norby site, representing a male dominated assemblage (Zurburg 1991:146). Although the female and immature sample is small, the Heron Eden measurements consistently fall below that of the Norby site. This is opposite to the expected trend. The female and immature data instead fall into the range seen at the Gowen sites, interpreted as nursery herds consisting of cows and calves with a small number of bulls (Morlan 1992:206). Consequently, this suggests the presence of both females/immatures and males at the Heron Eden site.

4.5.2 Metapodials

The second most common and complete elements are the metacarpals and metatarsals. Both univariate and multivariate analyses were completed for the metapodials following those outlined by Bedord (1974).

Even though Bedord (1974:199-240) gives 13 measurements for the analysis of metapodials, only three are needed to determine gender. Bedord follows Lorrain (1968 taken from Bedord 1974:214) who plots measurement No. 4 (transverse width of the distal end) against Ratio 6 (transverse width at the center of the shaft [measurement No. 3]/greatest length [measurement No. 1] x 100). Since only elements with fused distal condyles

are used for these analyses, bimodal clusters are interpreted as either mature male or mature female groups.

Similarly, for the majority of the specimens, gender may be simply determined by the mathematical comparison of the above two variables. Bedord states that:

> Specifically for metacarpals, if measurement No. 4 is greater than (90-1/2[Ratio 6]), then the bone is probably male, and if measurement No. 4 is less than (80-1/2[Ratio 6]), then the bone is probably female. For metatarsals, ... if measurement No.4 is greater than (76.5 -1/3[Ratio 6]), then the bone is probably male and if measurement No. 4 is less than (67.5-1/3[Ratio 6]), the bone is probably female [Bedord 1974:239].

For specimens that have single variables and when measurements occur between the values of male and female, the entire population of measurements are plotted and gender determinations can be made visually.

Nineteen metacarpals and 13 metatarsals are mature and sufficiently complete for metric analyses. Of the metacarpals, 10 are specified as mature males and two as mature females (Table 4.5). Five other metacarpals, for which one variable could not be calculated, are thought to be those of males because, when plotted, their values fall into the size range defined by those assigned as mature males. Similarly, two additional specimens are included in the female grouping.

Of the 13 metatarsals, 11 are sufficiently complete for mathematical comparison. Nine are identified as mature male, one as probable male, and one as probable female (Table 4.6). When these data are plotted, two definitive clusters, containing 10 males and one female, occur. Two additional metatarsals, when plotted, are decidedly male and female respectively.

Table 4.5 Metacarpal values for determining gender.

Specimen	M4*	R6*	90-1/2(R6)	80-1/2(R6)	Male	Female
62	-	19.3				F?
217	-	23.5			M?	
885	81.0	23.0	78.5	68.5	M	
886	89.5	24.3	77.8	67.8	M	
946	89.0	23.8	78.1	68.1	M	
1050	68.5	17.2	81.4	71.4		F
1057	-	17.2				F?
3165	80.0	22.2	78.9	68.9	M	
3559	85.0	-			M?	
4241	80.5	23.0	78.5	68.5	M	
4885	-	23.0			M?	
5718	65.0	16.7	81.6	71.6		F
6714	-	24.7			M?	
6789	82.0	-			M?	
7845	80.5	25.0	77.5	67.5	M	
7885	83.0	24.8	77.6	67.6	M	
8726	82.0	23.1	78.5	68.5	M	
8881	84.0	23.8	78.1	68.1	M	
8929	83.5	23.4	78.3	68.3	M	

*M4 = metacarpal measurement 4; R6 = Ratio 6.

Table 4.6 Metatarsal values for determining gender.

Specimen	M4*	R6*	76.5-1/3(R6)	67.5-1/3(R6)	Male	Female
133	64.5	12.8	72.2	63.2		F?
666	63.0	-				F?
2550	72.5	15.9	71.2	62.2	M	
3775	73.0	14.2	71.8	62.8	M	
4408	73.5	16.2	71.1	62.1	M	
5839	73.0	16.3	71.1	62.1	M	
6907	74.0	14.9	71.5	62.5	M	
6908	77.0	14.7	71.6	62.6	M	
7672	76.0	16.0	71.2	62.2	M	
7862	70.0	14.9	71.5	62.5	M?	
7913	73.0	14.6	71.6	62.6	M	
8609	72.5	14.0	71.8	62.8	M	
9630	73.0	-			M?	

*M4 = metatarsal measurement 4; R6 = ratio 6.

When these results are combined (Table 4.7), approximately 7.1% of the specimens are in the mature female range, 30.6% in the mature male range, and 62.4% are of indeterminate gender. Thus, these results also indicate a preponderance of males among the measurable specimens.

Table 4.7 Summary of metapodial gender determination.

	MNE	Female		Male		Indeterminate	
		N	%	N	%	N	%
Metacarpal	44	4	9.1%	15	34.1%	25	56.8%
Metatarsal	41	2	4.9%	11	26.8%	28	68.3%
Metapodials	85	6	7.1%	26	30.6%	53	62.4%

An under-representation of specimens in the female/immature range occurs because only mature specimens are examined. For example, one metacarpal and three metatarsals, with unfused epiphyses, are not included in this analysis (Appendix B). Additionally, one immature metacarpal and four immature metatarsals are sufficiently weathered and fragmented that they are not measurable (Figure 4.10). They are qualitatively described in comparison to an eight month old bison specimen in the University of Saskatchewan comparative collection. The nearly complete metacarpal is the same length as the comparative specimen but the shaft is greater in depth and breadth. The metatarsals differ in completeness. Two proximal and shaft portions are similar in size and one proximal and shaft portion is larger than the comparative specimens. The remaining shaft, although similar in length, is smaller in breadth and depth than the comparative specimen.

Figure 4.10 Three immature metatarsals from the Heron Eden site.

As was noted with the carpals and tarsals, immature specimens are present in the faunal assemblage, although it is difficult to quantify their presence. This is likely due to the more severe attrition of less dense immature elements. Bedord (1974:240) also notes that immature metapodials are less likely to survive poor preservation conditions. Thus, this frequently produces a skewed distribution to the site sample.

Univariate comparisons of the Heron Eden metapodials, utilizing all 13 measurements, were made of four assemblages of different composition (Tables 4.8 and 4.9). The Casper site, consisting of a female and immature herd, the Olsen-Chubbuck site, having more females than males, and the Finley site, having mostly males, all date to approximately 9000 years ago (Bedord 1974). The Norby site, which dates to approximately 6,000 years ago, is also dominated by males (Zurburg 1991). Only mature elements are included and both male and female specimens are used collectively.

		M1	M2	M3	M4	M5	M7	M8	M9	M10	M11	M12	M13
Heron Eden	Min.	192.0	64.0	35.0	65.0	22.0	38.0	35.0	24.0	35.0	164.5	142.5	140.5
	Max.	223.5	85.5	54.0	89.5	34.0	50.5	44.5	32.0	54.5	194.0	170.5	165.5
	Mean	214.2	77.0	47.7	81.0	30.5	45.1	40.7	28.7	47.6	182.8	160.7	153.9
	s.d.	9.1	7.5	7.0	6.7	3.5	3.9	2.8	2.2	7.1	7.3	7.0	6.6
*Casper	Min.	200.0	65.0	36.0	70.0	26.0	38.0	34.0	23.0	36.0	171.0	145.0	139.0
	Max.	224.0	85.0	55.0	91.0	35.0	51.0	46.0	32.0	55.0	198.0	169.0	165.0
	Mean	213.4	71.7	43.0	75.5	29.6	42.8	39.7	27.6	43.0	182.5	159.0	153.5
	s.d.	6.5	4.3	3.9	4.9	2.0	2.8	2.1	1.7	3.8	6.0	6.0	5.5
*Olsen-Chubbuck	Min.	201.0	64.0	37.0	68.0	26.0	40.0	27.0	25.0	37.0	169.0	153.0	142.0
	Max.	229.0	85.0	56.0	90.0	35.0	51.0	49.0	33.0	56.0	194.0	175.0	163.0
	Mean	215.7	73.3	44.0	76.3	29.9	44.2	40.9	28.1	43.6	183.4	162.8	154.8
	s.d.	6.8	6.0	5.6	5.6	2.5	3.2	2.7	1.9	5.6	5.8	5.1	4.9
*Finley	Min.	201.0	64.0	32.0	66.0	24.0	37.0	36.0	24.0	36.0	171.0	145.0	142.0
	Max.	230.0	88.0	54.0	88.0	37.0	52.0	46.0	32.0	54.0	196.0	170.0	165.0
	Mean	215.7	75.1	46.3	78.8	31.2	46.0	41.1	28.6	45.9	183.9	161.3	154.6
	s.d.	7.1	6.4	5.2	6.3	3.1	3.9	2.7	2.0	5.2	6.1	5.1	5.2
**Norby	Min.	199.0	68.0	45.0	69.0	28.0	42.0	36.0	26.0	45.0	168.0	150.0	141.0
	Max.	222.0	82.0	54.0	87.0	34.0	49.0	45.0	31.0	53.0	187.0	170.0	164.0
	Mean	213.8	76.8	47.5	79.7	31.4	45.1	40.9	28.5	48.0	181.1	161.3	153.7
	s.d.	6.5	3.6	2.5	3.3	1.5	1.8	2.3	1.3	3.0	5.6	5.9	6.3

* Data taken from Bedord (1974:205-225); **Data taken from Zurburg (1991: Table A2.3).

Table 4.7 Univariate comparisons of metacarpal measurements

Site		M1	M2	M3	M4	M5	M6	M8	M9	M10	M11	M12	M13
Heron Eden	Min.	259.5	54.0	34.0	64.5	32.5	52.0	37.0	28.0	33.0	216.0	188.0	191.0
	Max.	283.0	65.0	44.0	77.0	40.0	59.5	44.5	35.0	43.5	239.5	207.5	209.0
	Mean	269.8	60.7	39.7	71.9	37.1	57.4	41.2	32.3	38.8	227.3	198.7	200.6
	s.d.	7.9	3.0	3.2	4.0	2.5	2.0	2.1	1.8	3.0	7.0	6.7	5.5
*Casper	Min.	242.0	52.0	31.0	63.0	31.0	48.0	33.0	27.0	30.0	205.0	175.0	182.0
	Max.	276.0	67.0	41.0	79.0	42.0	61.0	46.0	35.0	40.0	236.0	207.0	214.0
	Mean	261.2	57.2	38.2	68.5	34.3	55.2	40.3	31.0	33.9	222.4	193.0	196.0
	s.d.	7.9	3.8	3.0	4.1	2.4	3.0	2.2	1.8	3.0	6.8	6.7	6.9
*Olsen-Chubbuck	Min.	247.0	51.0	30.0	61.0	33.0	53.0	34.0	30.0	30.0	211.0	187.0	186.0
	Max.	280.0	65.0	42.0	77.0	41.0	66.0	47.0	35.0	42.0	237.0	211.0	214.0
	Mean	258.7	58.7	37.0	70.8	37.2	59.4	41.4	32.2	36.0	226.2	198.4	200.2
	s.d.	4.4	4.4	4.4	4.6	2.6	4.3	2.8	1.5	3.9	6.7	6.1	7.0
*Finley	Min.	253.0	52.0	32.0	60.0	31.0	51.0	36.0	28.0	30.0	216.0	185.0	189.0
	Max.	284.0	67.0	47.0	79.0	41.0	63.0	46.0	35.0	44.0	237.0	209.0	210.0
	Mean	268.8	60.2	38.7	71.4	36.6	57.0	40.9	31.8	36.2	226.9	197.9	199.6
	s.d.	7.0	4.1	3.4	4.7	2.9	3.5	2.5	1.8	3.3	5.7	6.1	6.3
**Norby	Min.	250.0	56.0	32.0	63.0	32.0	55.0	38.0	30.0	31.0	213.0	185.0	187.0
	Max.	285.0	71.0	42.0	78.0	41.0	63.0	45.0	34.0	40.0	237.0	210.0	210.0
	Mean	269.8	61.1	38.2	71.8	36.5	57.8	41.4	32.0	36.0	228.0	199.9	201.5
	s.d.	8.6	4.0	2.7	3.1	2.6	2.8	1.6	1.1	2.6	7.1	6.7	6.2

* Data taken from Bedord (1974: 205-225); ** Data taken from Zurburg (1991: TableA2.3).

Table 4.8 Univariate comparisons of metatarsal measurements

Both the metacarpals and metatarsals from the Casper site have constant smaller mean values (refer to Tables 4.8 and 4.9). Accordingly, this indicates that the Heron Eden assemblage contains more male specimens. While the Olsen-Chubbuck metacarpals are similar in average size, the metatarsals are generally smaller. Although the metacarpals from the Finley site have slightly larger mean values, the metatarsals are consistently smaller. These data generally suggest that the Heron Eden metapodials are similar in stature to those of the Olsen-Chubbuck and Finley sites. The more recent Norby site metapodials have mean values similar to those from the Heron Eden site. The Norby site metacarpals typically have larger minimum and smaller maximum values. The metatarsal values are comparable, the minimum being slightly smaller and the maximum larger. These data indicate the presence of both female/immatures and males in the Heron Eden metapodial assemblage

4.5.3 Long Bones

To complement the results of gender analyses and the subsequent discussions of bison species identification, long bone analysis following the methods outlined by Todd (1987a) was undertaken. The measurement codes used and the description of measurements taken on the Heron Eden site long bones follow those outlined by Todd (1987b).

Due to the fragmentary nature of the Heron Eden site faunal material, only a limited number of measurements could be taken. The femora are completely broken, as are proximal humeri and proximal tibiae. The measurable elements include distal humeri (N = 7), proximal radii (N = 12), distal radii (N = 7), proximal ulnae (N = 11), and distal tibiae (N = 13). To increase the sample size, all possible specimens were utilized regardless

of the stage of maturity. When possible, mature specimens were noted. All measurements defined by Todd (1987b) were taken (Appendix B), but only limited combinations could be used for bivariate plots to determine gender. Only those measurements used for the bivariate plots were utilized in the univariate analysis.

Distal tibiae, the largest sample, were plotted along with the equivalent measurements from the Horner site (Todd 1987b:399-402). Only mature specimens, with fused proximal epiphyses, were used from the Horner site. The Heron Eden tibiae cluster into two groups (Figure 4.11), two specimens in the female range and nine in the male range. The two Heron Eden specimens in the female range could be females or immature males since their maturity is not known.

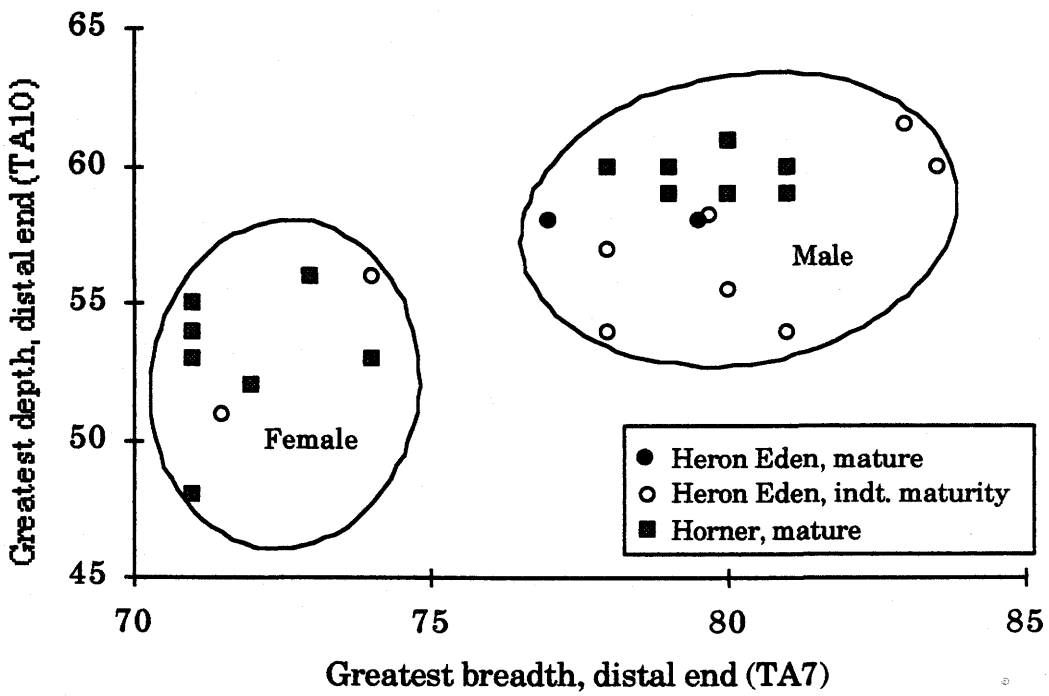


Figure 4.11 Tibia bivariate plot of Heron Eden site tibiae with mature tibiae from the Horner site (Todd 1987b:399-402).

It is also possible to estimate the gender of fragmentary specimens, once bivariate plots, showing clustering along two dimensions, provide the basis for the separation (Todd 1987a:162). Accordingly, one additional tibia is assigned to the female and immature group at 2.0 s.d. (Table 4.10). Table 4.10 also shows the results of the humeri, radii, and ulnae bivariate plots and estimates. When the measurable specimens are combined, 2.5% (N = 4) are interpreted as being female/immatures, 10.6% (N = 17) as being male, and 86.9% (N = 139) are of indeterminate gender. The indeterminate category includes both specimens which fall outside the male and female ranges and those which could not be plotted.

Table 4.10 Long bone gender determinations.

		Bivariate data			2.0 Standard deviations		
Element	MNE	Female/ immature	Male	Indt.	Female/ immature	Male	Indt.
Humerus	41	0	4	37	1	6	34
Radius	40	1	2	37	2	4	34
Ulna	42	1	2	39	1	2	39
Tibia	37	2	9	26	3	9	25
N	160	4	17	139	7	21	132
Percent		2.5%	10.6%	86.9%	4.4%	13.1%	82.5%

It is apparent from the tibia bivariate plot that the Heron Eden distal tibiae are in a range similar to the Horner site tibiae. Thus, univariate comparisons of select long bone measurements from the Heron Eden site

were made with the mature long bone data provided in the Horner site report (Todd 1987a:165-176).

Regardless of which element measurement is considered, all of the female/immature specimens from the Heron Eden site fall into the ranges defined by 2.0 s.d. of the Horner mature female materials (Table 4.11). The majority of the Heron Eden specimens identified as male fall into or above the range defined by 2.0 s.d. of the Horner mature male specimens. The only deviation from this pattern is the tibia "greatest depth of the distal end" (TA10) (Table 4.11). Four of the Heron Eden TA10 measurements fall into the range defined by 2.0 s.d. of the Horner mature male materials and one specimen is above this range. However, four of the Heron Eden TA10 specimens, of indeterminent maturity, are below the male rank into the range defined by 2.0 s.d. of the mature Horner female range. However, since the bivariate plot (Figure 4.11) indicates that these specimens are in the male cluster, they are considered as representing immature males large enough to be included in the male group.

Thus, univariate analyses indicate that the size of the female elements are comparable to those of the Horner site and that the majority of the specimens identified as male fall into or above the range of the Horner site measurements. Since the Horner site contains more females and immatures than males (Todd 1987a:195), this suggests the presence of both male and female/immature specimens in the Heron Eden site faunal assemblage.

Table 4.11 Comparison of select long bone measurements from the Heron Eden site with the Horner site.*

Measurement	Female					Male				
	No.	Mean	Min	Max	S.D.	No.	Mean	Min	Max	S.D.
HM7										
Heron Eden	-	-				4	102.3	98.5	106.0	3.1
Horner	13	83.2	80.0	87.0	2.7	10	99.8	97.0	103.0	2.0
HM14										
Heron Eden	-	-				4	49.6	46.5	54.5	3.4
Horner	13	42.1	39.0	45.0	1.8	11	48.8	46.0	52.0	1.7
RD7										
Heron Eden	1	80.0				2	102.5	101.0	104.0	2.1
Horner	16	81.9	75.0	88.0	3.1	15	97.5	93.0	102.0	2.4
RD11										
Heron Eden	1	55.0				2	68.0	66.0	70.0	2.8
Horner	15	57.5	53.0	63.0	2.7	13	67.2	64.0	71.0	2.0
UL3										
Heron Eden	1	119.0				2	153.0	152.0	154.0	1.4
Horner	17	115.9	110.0	123.0	3.6	10	148.9	145.0	153.0	2.6
UL7										
Heron Eden	1	58.5				2	75.3	75.0	75.5	0.4
Horner	15	59.8	54.0	64.0	3.1	10	71.6	68.0	77.0	3.0
TA7										
Heron Eden	2	72.8	71.5	74.0	1.8	9	79.9	77.0	83.5	2.2
Horner	9	71.2	69.0	74.0	1.6	8	79.4	77.0	81.0	1.4
TA10										
Heron Eden	2	53.5	51.0	56.0	3.5	9	57.3	54.0	61.5	2.5
Horner	9	52.9	48.0	56.0	2.3	8	59.5	58.0	61.0	0.9

*Horner site data from Todd (1987a).

4.5.4 Summary

The various methods employed to determine gender at the Heron Eden site suggest the preponderance of male specimens in the assemblage (Table 4.12). But, as previously noted, there is an under-representation of immature specimens in the female/immature group. Altogether, the results

suggest the presence of both males and female/immatures in the faunal assemblage. Nevertheless, when the metrics derived for the male and female/immature groups are compared to those of other sites, it is suggested that the bison present at the Heron Eden site are members of an extinct chronosubspecies.

Table 4.12 Summary of gender determination results using the bivariate data only.

Analysis type	Female/immature	Males	Indeterminate
Carpals/tarsals	7.4%	53.7%	38.9%
Metapodials	7.1%	30.6%	62.4%
Long bones	2.5%	10.6%	86.9%

4.6 Herd Structure and Species Identification

It is generally accepted that bison have gradually diminished in body size throughout the Holocene. Wilson (1974, 1978) suggests that two early subspecific variants of *B. bison* are present during the early Holocene, *B. b. occidentalis*, a northern variant, and *B. b. antiquus*, a southern variant. He also suggests that there is a:

> ... time transgressive southward onlap of "*occidentalis*"-like populations. ... In other words, the zone of integration between ... the two taxa was further north during the earliest Holocene (ca. 10,000 years B.P.) than it was during the later portions of the early Holocene (ca. 7,000 years B.P.) [Wilson 1978:11].

McDonald (1981), on the other hand, views these two forms as distinct species, *B. a. occidentalis* being a transition form between *B. a. antiquus* and modern *B. bison*. He considers *B. a. occidentalis* a highly variable subspecies

of *B. a. antiquus*, not *B. bison* (McDonald 1981:259). He suggests that:

> *B. a. antiquus* and *B. a. occidentalis* were apparently contemporaneous during much if not all of the transition period (ca. 11.000-5,000 BP). *B. a. occidentalis* apparently represented regional populations of the species, populations that first appeared on the western plains ... whereas *B. a. antiquus* populations shifted northward [McDonald 1981:258-259].

In Wilson's 1974 initial view, *B. b. occidentalis* is simply the northern counterpart of the contemporaneous *B. b. antiquus* (Wilson 1992:8). He more recently notes:

> That there is still evidence in favor of this view; nevertheless, it is extremely interesting that the finds of *B. antiquus* from Alberta ... seem largely or entirely to predate 10 000 b.p., while the finds of *B. occidentalis* ... 9600 year old ... postdate this time [Wilson 1992:8-9].

Suggestions for the explanation of these finds include the southern time transgressive movement of *B. occidentalis*, the replacement of *B. antiquus* through interbreeding, or that *B. antiquus* became extinct at the same time as the Pleistocene extinctions of mammoths, horses, and camels, which would favor a species "distinction between *antiquus* and *occidentalis*" (Wilson 1992:9).

The relationship between the two forms has been the subject of much debate in the past and this debate will likely continue as the current knowledge base expands. In any case, these taxonomic distinctions are made largely on cranial and horn core metric and non-metric observations (Wilson 1974; McDonald 1981). The absence of complete crania or horn cores in the Heron Eden faunal assemblage prevents the confident assignment to a bison subspecies. However, tentative taxonomic identification can be suggested based on the univariate comparisons of post-cranial element measurements, since these also indicate the continuous dwarfing of bison throughout the Holocene (Bedord 1974; Zeimens and Zeimens 1974; Frison 1991; Zurburg 1991; Morlan 1992).

The Heron Eden female/immature carpal and tarsal measurements compare favorably to those of the Gowen sites, which represent an extinct chronosubspecies (Walker 1992:101, Morlan 1992:206), possibly *B. b. occidentalis* (E.G. Walker, personal communication 1995). The female/immature group long bone measurements are similar to the Horner site materials, tentatively assigned as *B. b. antiquus* (Walker 1987:342). The male group carpal and tarsal measurements are, on average, larger than those of the Norby site, representing probable *B. b. occidentalis* (Zurburg 1991:126). The male group long bone measurements are similar to slightly larger than the Horner site materials.

The Heron Eden metapodials, which were analyzed collectively, are similar in date, herd structure and size to the Finley and Olsen-Chubbuck sites. The Heron Eden specimens are consistently larger than those at the Casper site, which is similar in antiquity, but smaller in general herd structure. The Casper site cranial material is identified as *B. b. antiquus* (Wilson 1974:132), the Finley site is comparable to the *B. b. antiquus* material from the Casper site (Todd and Hofman 1987:495), and the Olsen-Chubbuck site (Wheat 1972) is similar in age to the Casper site. As well, the Heron Eden metapodials have similar mean values to the later Norby site, which also has a different herd structure. In general, the male metapodials from the Heron Eden site display larger metric values than the Norby site specimens, the females lowering the assemblage mean.

As shown, the Heron Eden bison postcranial female specimens are similar to those identified as possible *B. b. occidentalis* and to those tentatively assigned as *B. b. antiquus*. The Heron Eden postcranial male specimens are larger than those identified as possible *B. b. occidentalis* and

similar to those identified as *B. b. antiquus*. On the basis of this analysis, it seems most likely that the Heron Eden bison assemblage represents *B. b. antiquus*. However, the absence of complete crania or horn cores prevents a more confident assignment of bison subspecies.

4.7 Seasonality and Age Structure

Dental characteristics, such as eruption and wear schedules and molar metaconid heights, provide information of site seasonality, age group distributions, and the type of kill represented (Reher 1973, Frison et al. 1976, and Reher and Frison 1980). Descriptions of tooth wear follow the dental facet numbering system presented by Reher and Frison (1980:66).

At the Heron Eden site, upper dentitions are not as well represented as the lower, consisting only of isolated teeth. As a result, mandibles and individual mandibular teeth were utilized. Six partial mandibular tooth rows, including three subadult and three adult dentitions, and 128 individual lower teeth were used in the analysis (Appendix C). Three isolated teeth, two third molars and one second molar, display anomalous occlusal wear patterns. Also, two third molars exhibit underdeveloped exostylids. No dental aberrations were noticed.

Initially, the three subadult dentitions were assessed for age and seasonality on the basis of tooth eruption and wear. Then, individual teeth were placed in appropriate groupings based on eruption and wear patterns. If the individual teeth are fully in wear, molar metaconid heights are used to attempt reconstruction of age groups.

4.7.1 Age Group Descriptions

Five younger age groups (Groups 1-5) were postulated based on tooth eruption and wear patterns, and on molar metaconid heights. These were defined by comparisons with the Wardell site (x.4, Reher 1973), the Horner and Finley sites (x.6 years, Todd 1987a and Todd and Hofman 1987), the Casper site (x.6 years, Reher 1974), the Hawken site (x.7, Frison et al. 1976), and the Norby site (x.7-.75, Zurburg 1991).

All older age groups have fully erupted molars. These are usually aged on the basis of several attributes: tooth wear or metaconid heights, the position of the molar enamel-root line to the alveolus, and exostylid wear (Todd and Hofman 1987). Due to the lack of socketed teeth, the older age groups at the Heron Eden site (Groups 6a-6d+) were distinguished on the basis of tooth wear alone. Todd and Hofman (1987) indicate that use of metaconid height for the determination of individual tooth age is not always accurate, but it does provide insight into the number of age groups present. Because of the small sample and the degree of weathering, additional older age groups are likely present within the original population but can not be determined with the present data.

The subadult dentitions and individual tooth ages imply a restricted seasonal mortality for the Heron Eden bison. Likewise the plotting of metaconid heights (Figure 4.12) for both the subadult and adult materials shows the stepwise regression interpreted to represent a seasonally restricted sample. Several areas of metaconid continuity in some late subadult and early adult tooth groups have been arbitrarily divided into adjacent age groups.

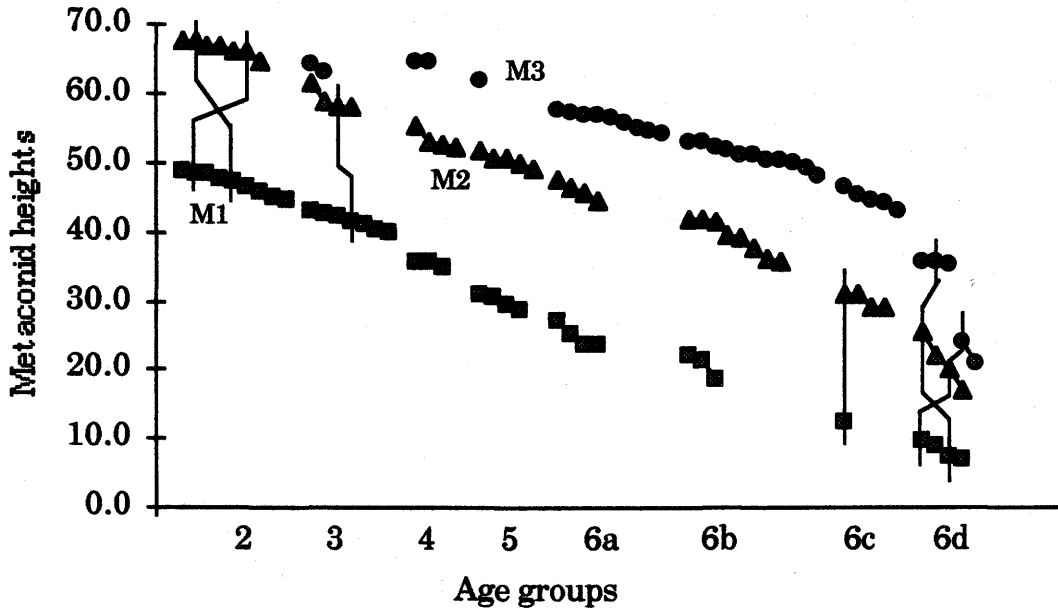


Figure 4.12 Regression of bison metaconid height (mm) by age group. Metaconid heights for socketed teeth indicated by adjoining lines.

The age groups for the mandibles at the Heron Eden site are:

Group 1: (0.6-0.7 years)

This group consists of seven isolated teeth. Two dP4's are in full wear; the posterior exostylid is in wear and joined to the crown, the anterior exostylid is 4 mm from wear. One M2, which is nearly complete and not yet in wear, and four developing M3's are included in this group.

Group 2: (1.6-1.7 years)

This is the largest immature group, with two partial tooth rows (dP3 - M2, M1 - M2) and 25 isolated teeth (Figures 4.13 and 4.14). One dP3 and dP4 are in place and in full wear. Four loose dP4's are also in full wear. The dP4's are worn level and both exostylids are in wear with the posterior exostylid joined to the crown and the anterior separate. All 10 M1's, are in full wear with the exostylids 4.0 to 8.6 mm (mean = 6.5 mm) from being in

wear. The eight M2's vary in wear from class 2 to 6 with most falling in wear class 4. Seven M3's are included because of the lack of wear and their enamel heights.

Figure 4.13 A partial mandible from age Group 2 (dP3 - M2).

Figure 4.14 A partial mandible from age Group 2 (M1 - M2).

Group 3: (2.6-2.7 years)

This group contains one partial tooth row (M1 - M2) and 16 isolated teeth (Figure 4.15). One loose dP4 is present with the anterior fossetid lost and both exostylids connected to the crown. Eight M1's and seven M2's are in full wear and are included based on metaconid heights. The M1 exostylids

are either beginning to wear or are less than 5.7 mm below the crown. The M2 exostylids are 11.6 to 18.8 mm (mean = 14.0 mm) from being in wear. Two M3's have wear on facets I and II with polish on facets III and IV.

Group 4: (3.6-3.7 years)

Six isolated teeth make up this group. Three M1's and one M2 are in wear on all cusps and are included based on metaconid heights. The M1 exostylids are in wear with one separated from the tooth by a continuous enamel ring and one connected to the enamel of the rest of the tooth. The M2 exostylid is not in wear. Two M3's exhibit wear on facets I to VI with one specimen having polish on facet VII. The hypoconulids are not in wear.

Group 5 (4.6-4.7 years)

This group includes 15 isolated teeth. Six M1's and eight M2's are placed in Group 5 based on metaconid heights. All M1 exostylid enamel joins the main part of the tooth to form a continuous surface. Four of the M2 exostylids are not in wear but, when wear is present, an enamel ring around the exostylid separates it from the main part of the tooth. All cusps of one M3 are in wear, but the hypoconulid is separate from the rest of the tooth.

Other Groups

Metaconid heights of three partial mandibles and 58 individual teeth are included in the older age groups. Group 6a (5.6 - 5.7 years) contains 18 isolated teeth, Group 6b (6.6 - 6.7 years) has 20 isolated teeth, Group 6c (7.6 - 7.7 years) includes 11 isolated teeth, and Group 6d+ (8.6 - 8.7+) consists of three partial mandibles and five isolated teeth. Individual specimens are not aged beyond Group 6d because of the variability seen in the wear of socketed teeth (Figure 4.13).

Based on the mean annual enamel heights given in Table 4.13, the rates of molar attrition can be calculated: 5.8 mm/year for M1, 6.1 mm/year

for M2, and 5.1 mm/year for M3, for a mean of 5.7 mm/year. Group 6d specimens are excluded from these calculations because the number of age groups represented is not known. This mean attrition rate is similar to other archaeological bison populations: 4.2 mm/yr. at the Casper site (Reher 1974:120), 5.4 mm/yr. at the Horner site (Todd and Hofman 1987:518), and 5.9 mm/year at the Agate Basin site (Frison 1982:250). Following Wilson's (1980:100) analysis of rates of molar attrition, the life expectancy of the Heron Eden bison is approximately 12 years.

Table 4.13 Mean molar metaconid height by age group.

Age group	Age in years	N M1*	Enamel height	N M2*	Enamel height	N M3*	Enamel height
1	0.6-0.7	-	-	-	-	-	-
2	1.6-1.7	9	47.0	7	66.8	-	-
3	2.6-2.7	7	41.0	4	59.2	-	-
4	3.6-3.7	3	35.4	4	53.4	2	64.8
5	4.6-4.7	4	29.9	5	50.5	1	62.1
6a	5.6-5.7	4	24.9	4	46.2	9	56.1
6b	6.6-6.7	3	20.8	8	39.1	11	51
6c	7.6-7.7	1	12.4	4	30.1	5	44.6
6d	8.6-8.7+	4	8.3	4	21.2	5	30.3

N = the number of measurable teeth in each group.

Examination of the eruption and wear patterns indicate age increments of x.6 to x.7 years for the Heron Eden site mandibular molars. Based on the assumption of a fairly constant birthing season from 15 April to 31 May, with peak calving between the end of April and mid-May (Rutberg 1984:418-420), the Heron Eden bison kill would have taken place sometime during December or January.

As previously noted, with the plotting of metaconid heights by age group (Figure 4.13), the subadult dentitions and individual teeth indicate a restricted season of mortality while the adult dentitions and individual teeth show a more weakly stepped distribution. Wilson notes that " the figure [Figure 4.13] considers only one characteristic, one which depends not only upon the extent of wear but also upon the original size of the tooth" (Wilson 1980:93). Therefore, a number of males mixed with females will cause some "fuzziness" in the groups.

If seasonal reconstruction for the Heron Eden site kill is correct, there should be a tendency for multimodal wear peaks in the metaconid heights of each molar group. Conversely, if seasonal reconstruction is misleading, there would be a more "level" series of wear patterns. Figures 4.15 to 4.17 shows the multimodal patterns of the metaconid heights, for each mandibular molar. Interestingly, the graphs indicate more than one peak within most defined age groups. This suggests the presence of two groups, a male herd and a female/ immature herd, in the Heron Eden site bison assemblage.

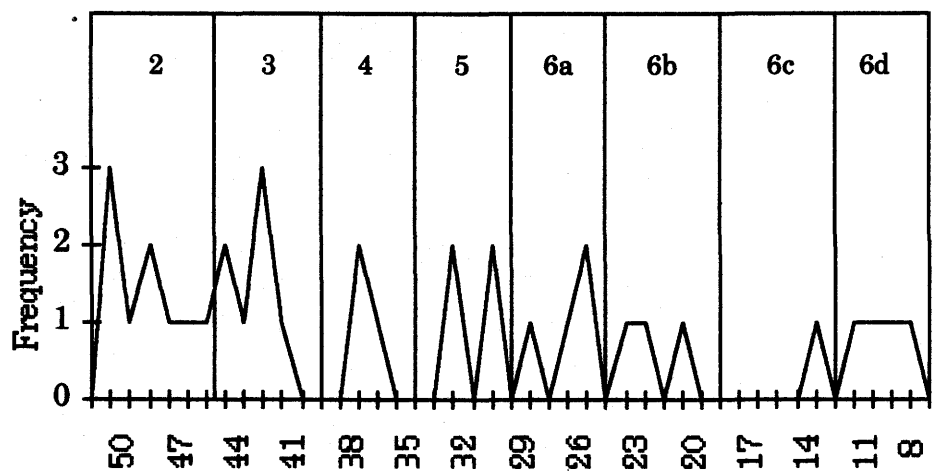


Figure 4.15 Frequency of M1 metaconid height by age group.

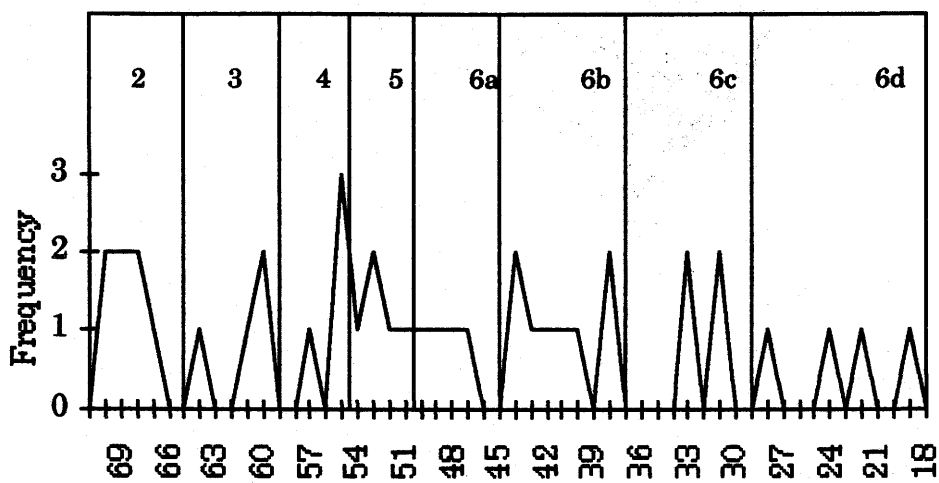


Figure 4.16 Frequency of M2 metaconid height by age group.

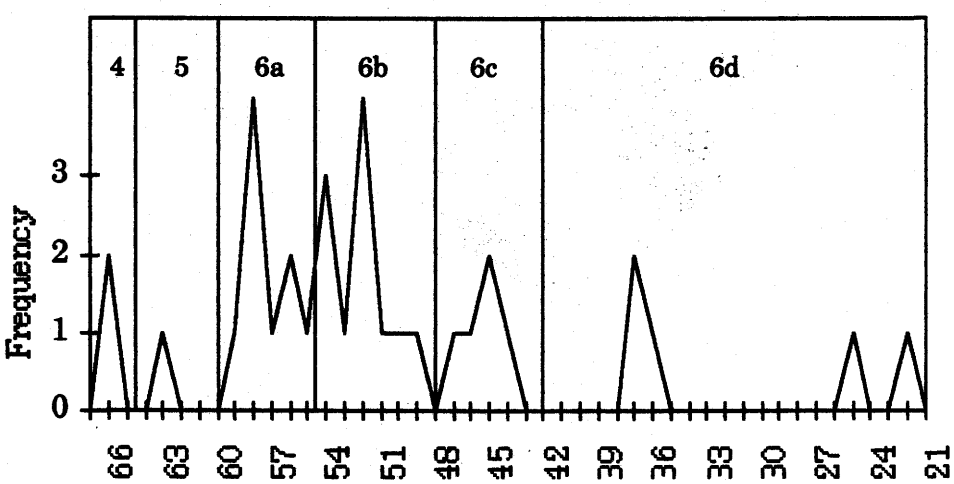


Figure 4.17 Frequency of M3 metaconid height by age group.

4.7.2 Population Structure

The plotting of tooth age group frequencies indicates the mortality structure of the herd present in an assemblage. A generalized "living-structure" mortality profile (Figure 4.18) represents the age group frequencies of a viable bison population consisting of male, female, and immature animals (Stiner 1991a:8). This mortality pattern is sometimes

called "nonselective" (Munson 1991:139) or "catastrophic " (Reher 1973:96, 1974:117-118). However, bison herd composition is seasonally variable. Nursery (female/ immature) herds and bachelor or bull (male) herds are separated for much of the year, only congregating during late summer and early fall to form a rutting herd (Reher 1974:123). Therefore, a bison assemblage with a living-structure mortality profile should reflect this seasonal variation in herd composition.

Figure 4.18 Generalized living-structure mortality profile.

In theory, a late summer-early fall death assemblage would resemble the generalized living-structure mortality profile. In the winter season, if a living-structure mortality profile of a male herd was added to that of a female/immature herd, the herd composition should resemble the generalized living-structure mortality profile. Since the Finley site contains more males than females (Haspel and Frison 1987:490) and the Horner site contains more females and immatures than males (Todd 1987a:195), and since the seasonality of both sites is (x.6) late fall-early winter (Todd and Hofman 1987:495), they are used as examples.

The Horner site and Finley site mortality curves do indicate differences in herd composition, the Finley site having a preponderance of viable adult members and the Horner site containing more subadult specimens (Figure 4.19a, b). They resemble the generalized living-structure mortality profile when combined (Figure 4.19c), allowing for the under-representation of some age groups, especially the subadult animals. Differential attrition of the younger less dense specimens and the differential human processing decisions concerning the age of the animals are possible causes for this divergence from the expected (Munson 1991:139; Reher 1974:121-122).

More important in this analysis, is the general resemblance of the Heron Eden site mortality profile (Figure 4.20) to the combined Horner site and Finley site profile (Figure 4.19c). To adjust for differences in the abundance of animals, the Heron Eden frequency axis is doubled in length. Other than slight differences in age group composition, possibly due to differential attrition or simply variation in the faunal samples, the mortality curves are similar. Therefore, these data indicate the presence of two kill events at the Heron Eden site, one involving a male or bull herd and the other a female/ immature or nursery herd.

The Hawken site mortality profile (Frison et al. 1976:41) is also presented (Figure 4.21). The Hawken bison population contains immature animals and an approximately equal number of mature males and females (Bedord 1974:239). The sample is from three separate levels and all are regarded as bison kills by the same group within a short time period (Frison et al. 1976:37). Again, other than slight differences in age group composition, the mortality curve is similar to that of the Heron Eden site. This further supports the presence of two herds in the Heron Eden site bison assemblage.

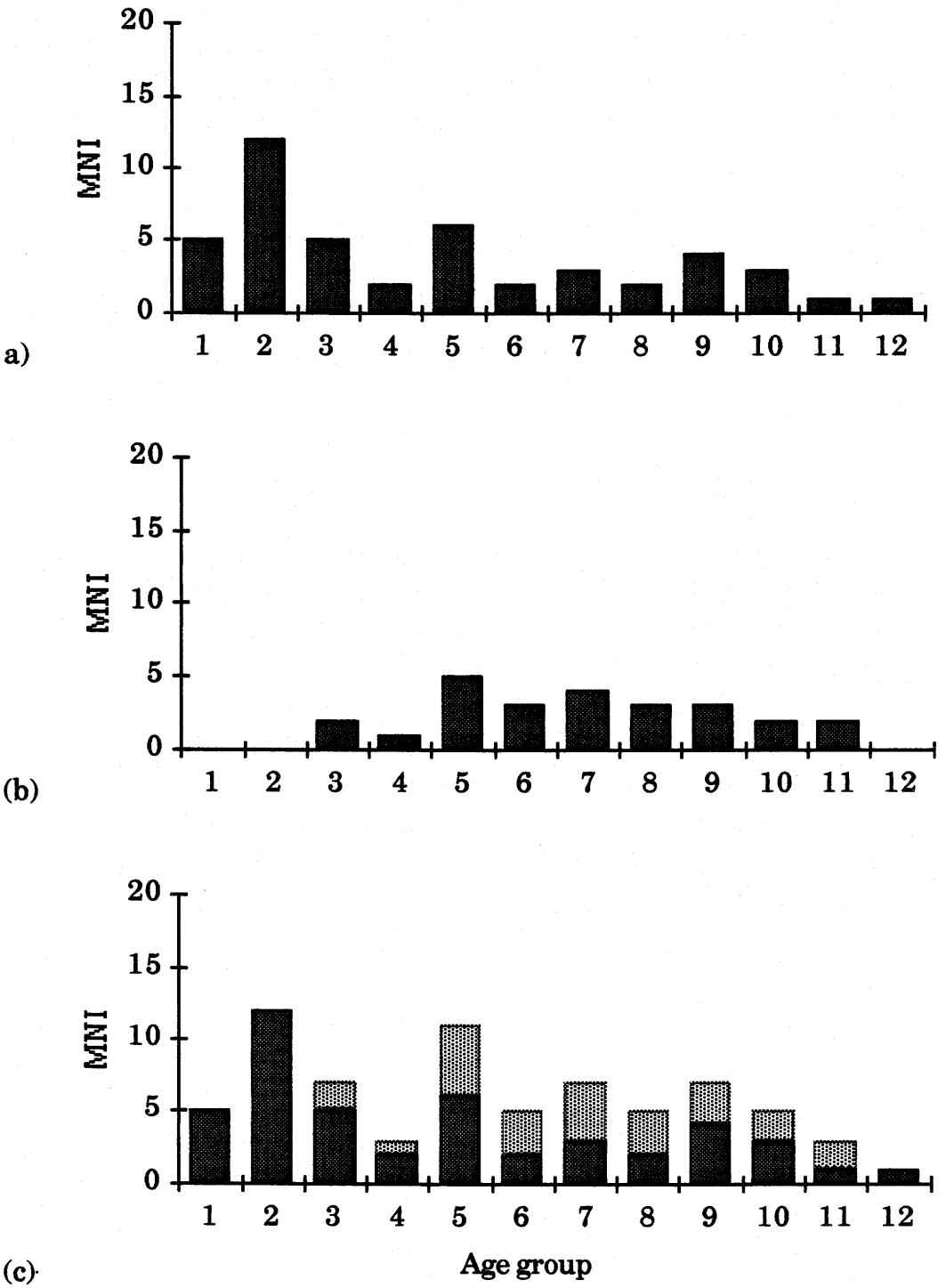


Figure 4.19 Mortality profiles recorded for the Horner (a), Finley (b), and the combined Horner and Finley sites (c) (Todd and Hofman 1987:528).

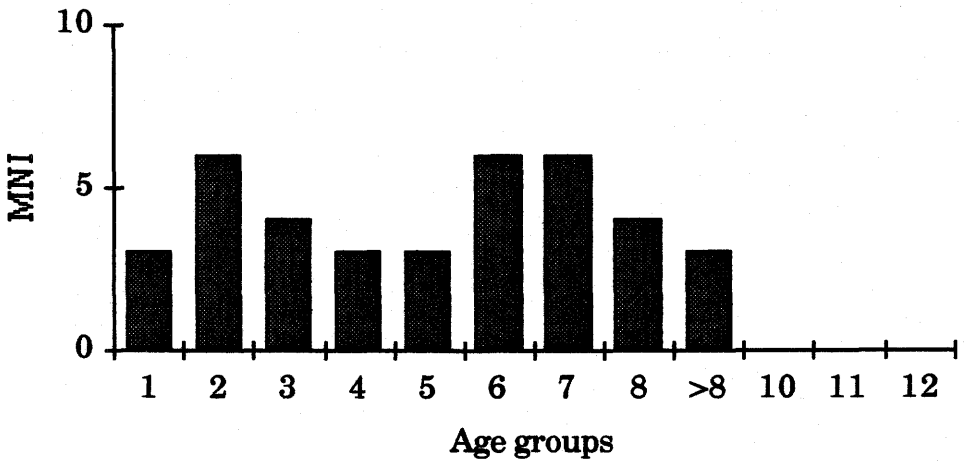


Figure 4.20 The Heron Eden site mortality profile.

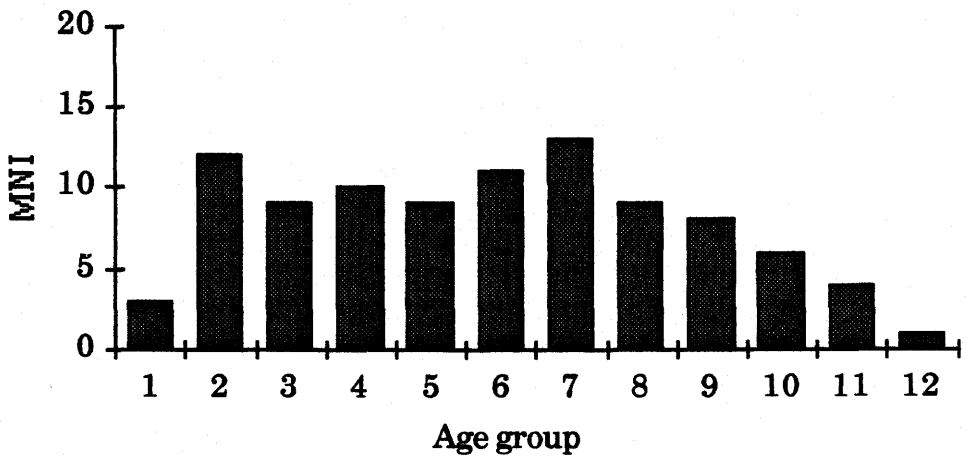


Figure 4.21 The Hawken site mortality profile (Frison et al. 1976:41).

4.8 Summary

The Heron Eden faunal assemblage is composed primarily of bison bone. Based on element counts, considering the left or right side, the bison assemblage contains a minimum of 37 animals. Other animals, which are associated and considered contemporaneous with the bison bone, include specimens representing one gray wolf (*Canis lupus*) and one Pronghorn (*Antilocapra americana*). All of the rodent materials are considered intrusive.

The distribution of faunal remains is characterized by a general decrease in bone weight per square meter around an area of central concentration. There is a lack of articulated elements and areas of special concentration. Additionally, no variation in the distribution of faunal material was noted.

The various methods employed to determine gender suggest a preponderance of male specimens in the assemblage. However, there is an under-representation of immature specimens as they are less likely to survive poor preservation conditions. Even when these specimens are present, they are largely unmeasurable and are not included in the quantitative analyses. Altogether, the results of the gender analyses indicate the presence of both female/immatures and males in the assemblage.

Examination of the mandibular dentition indicates age group increments of x.6 to x.7 years for the Heron Eden site bison. The subadult dentitions, when metaconid heights are plotted, show a stepwise regression which indicates a seasonally restricted sample. Based on the assumption of a seasonally restricted birthing season, these data indicate that the bison kills took place sometime during December or January.

The age group frequencies indicate the presence of a mixed herd living-structure mortality profile in a season when the bull (male) herd should be separate from the nursery (female/immature) herd. Hence, these analyses indicate that two separate bison kills occurred at the Heron Eden site. The mass kills of a nursery herd and a bull herd occurred within a relatively short time period, sometime during December or January.

CHAPTER 5

TAPHONOMY OF THE FAUNAL ASSEMBLAGE

5.1 Introduction

Understanding the formational history of archaeological bone beds involves reconstructing the processes that have gone into the development of that bone bed. Investigations into the cause of death, cultural modification and use, post-occupational modifications, and post-depositional processes are required for interpretations of cultural faunal procurement and utilization (Todd 1987a:194-198). There are problems in distinguishing between the effects of human occupational or cultural processes, post-occupational modifications, and post-depositional processes, as each subsequent modification can bias the effects of previous processes. Recognition of these biases is one of the initial steps in interpreting an assemblage.

Taphonomy provides a means for separating these biases. The term taphonomy, first proposed by I.A. Efremov, denotes the passage of organisms from the biosphere to the lithosphere (Gifford 1981). More specifically, the taphonomic approach focuses on the accumulation and modification of faunal assemblages from a site formation perspective (Gifford 1981). In general, taphonomic analysis attempts to reconstruct the "taphonomic history", the sequence of taphonomic agents and processes which have affected the faunal assemblage (Lyman 1994a:3).

Understanding how taphonomic processes affect site formation has been the focus of much research. The development of these analyses have been reviewed by Lyman (1994a) and others (Behrensmeyer and Hill 1980,

Binford 1981, Gifford 1981, Johnson 1985, Klein and Cruz-Uribe 1984, Lyman 1987) and will not be outlined here. However, background information that is pertinent to this study will be presented.

This chapter focuses on the degree to which the structure and content of the Heron Eden kill-butchery bone bed can be considered the result of cultural or natural processes, or a combination of both. Discussion will focus on attritional processes, bone fragmentation and distribution, and skeletal part frequencies.

5.2 Attritional Factors

The preservation of the faunal assemblage at the Heron Eden site was generally poor, although some of the bones were in exceptional condition. Differential preservation was noted in different areas of the bone bed, as well as on individual elements. For example, the smaller, more compact bones such as the carpals and tarsals weather more slowly than less dense elements. Furthermore, the micro-environment in terms of exposure, temperature, and moisture also affects the rate at which bones weather (Behrensmeyer 1978:152-156). More specifically, weathering is defined as:

> The process by which the original microscopic organic and inorganic components of bone are separated from each other and destroyed by physical or chemical agents operating on the bone in situ, either on the surface or within the soil zone [Behrensmeyer 1978:153].

To determine the degree of weathering at the Heron Eden site, Behrensmeyer's (1978:151) six weathering stages for cortical bone, as modified by Todd et al. (1987:Table 3.3), were used (Table 5.1). The extremes of weathering exhibited by the Heron Eden site faunal assemblage ranged from stage 2 (limited surface weathering with some cracking) to stage 6

(bone severely deteriorated and falling apart). Overall, the majority of the faunal assemblage was fragmented and in a poor state of preservation.

Table 5.1 Weathering stages for cortical and compact bone*.

Stage	Weathering, compact bone
1	Unweathered, articular surfaces intact with no surface cracking
2	Articular surfaces intact with some surface cracking
3	Articular surfaces exhibit some deterioration, but more than 50% of the surface remains intact
4	Intact articular surfaces restricted to a few small "islands;" less than 50% of articular surfaces remain intact
5	No articular surface area remains intact
6	Bone severely deteriorated; large areas of fibrous bone exposed

Stage	Weathering, cortical bone
1	Unweathered
2	Limited surface weathering, some longitudinal cracking
3	Light surface flaking, deeper cracking
4	Patches of fibrous bone with moderate flaking and cracking
5	Deep cracking and extensive surface flaking
6	Bone falling apart

*Taken from Todd et al. (1987: Table 3.3).

Some of the more complete elements, the metapodials and astragali, were examined for variations of weathering. Weathering was assessed for both the anterior and posterior surfaces of each element because variability in weathering provides indications of the pre-depositional stability of the bone (Todd et al. 1987:67). Differences in the structure of cortical and compact bones result in different types of surface alteration; thus, separate sets of codes were used for the metapodials and astragali (Table 5.1). Since the specimens from the plowzone were affected by cultivation, only the elements from the paleosol were examined.

The weathering of the astragali ranged from stage 2, where the articular surfaces are intact with some surface cracking, to stage 6, where large areas of fibrous bone are exposed (Figure 5.1). The majority of the astragali are within weathering stage 4, where less than half of the articular surface remains intact (Figure 5.2). In most cases, both the anterior and posterior surfaces of the elements are equally weathered (Figures 5.3). The weathering of the metapodials (Figure 5.4) range from lightly weathered (stage 2) to extremely weathered (stage 6). The majority of the more complete metapodials are within weathering stage 4 and 5 with moderate to heavy surface flaking with deeper cracking.

Figure 5.1 Weathering stages 2 to 6 shown by the posterior surface of bison astragali from the Heron Eden bone bed.

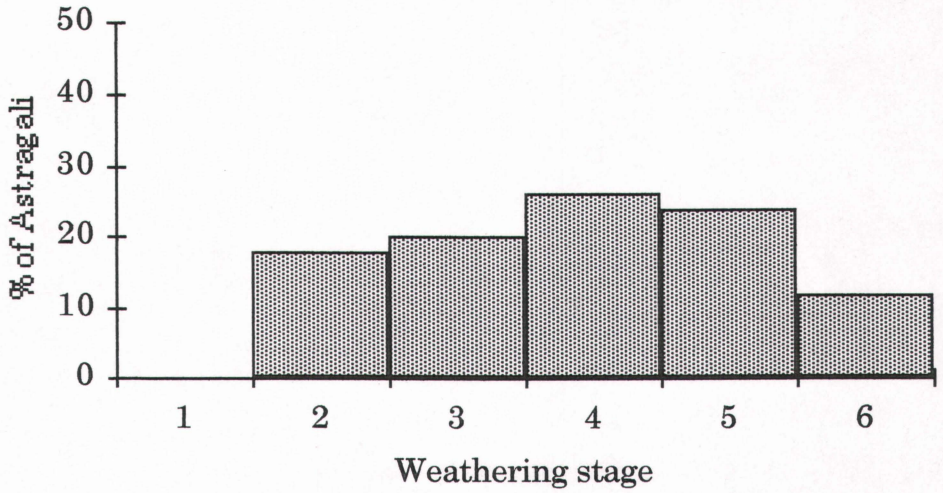


Figure 5.2 Weathering profile showing percent astragali in each stage (adapted from Lyman and Fox 1989).

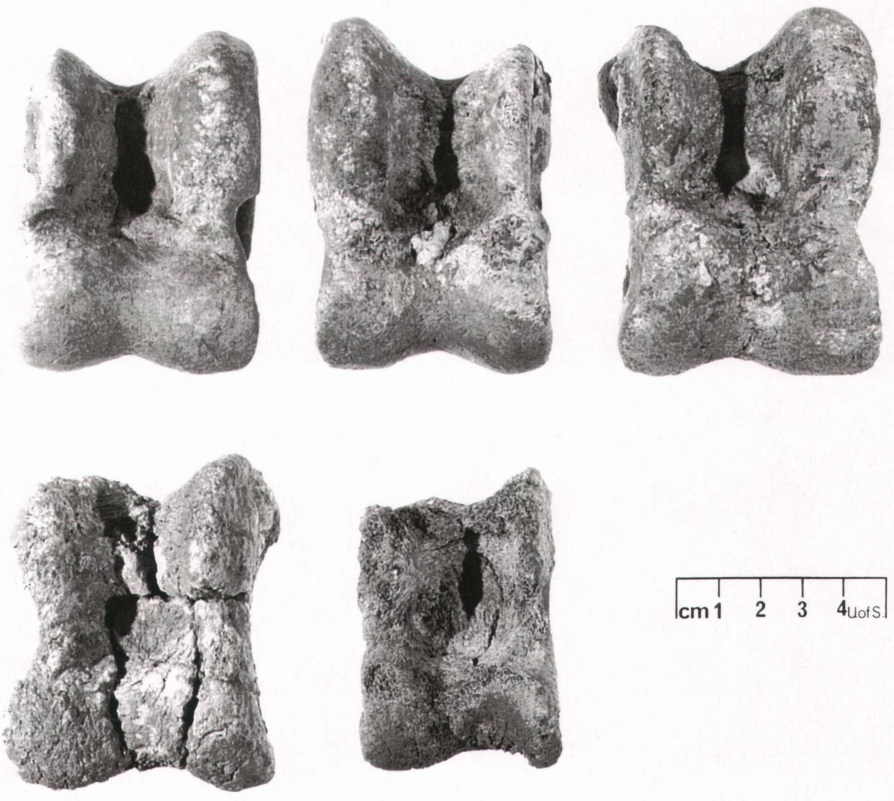


Figure 5.3 Weathering stages 2 to 6 shown by the anterior surface of bison astragali. This is the opposing view to the astragali in Figure 5.1.

Figure 5.4 Weathering stages 2, 4, and 6 on bison metacarpals. This is the maximum weathering exhibited on one anterior and two posterior surfaces.

Variability was noted in the degree of weathering for the individual elements and within the faunal assemblage. Many different combinations of weathering were observed on the Heron Eden metapodials. The weathering of the anterior surface exceeds the posterior surface, the posterior surface exceeds the anterior surface, the posterior and anterior surfaces are similar, and at times, either the lateral or medial sides exhibit the maximum stage of weathering.

Much of the bone exhibited uniform weathering on all surfaces. However, in some cases the most extreme attrition was observed on the upper surface of the element. A "pattern of marked difference in weathering stages on opposite surfaces of individual elements indicates that the subaerial position of the elements was quite stable prior to burial" (Todd et al. 1987:68). As well, " in some case bones are more weathered on lower than upper surfaces. This usually occurs on high alkaline soils where salts ... crystallize on the bone surfaces" (Behrensmeyer 1978:154). An increase in the quantity of calcium carbonate was observed at the Heron Eden site as the depth below the surface increased. This "salt" especially coated the underside of the elements that were located deepest below the surface. The deepest extent of the paleosol is in the eastern portion of the excavation area. When sparse, the carbonate coating would dissolve in routine laboratory cleaning and remove a small amount of the outer bone surface. When abundant, this coating would either exfoliate in large chips or remain cemented to the bone. In all cases the presence of calcium carbonate obscures the effects of any preceding bone modification processes.

Other natural processes can also contribute to the modification of individual elements and the faunal assemblage as a whole. Discussions on bone modification variables, both element and assemblage, are given by Bonnichsen and Will 1990, Erlandson 1984, Marshall 1989, Morlan 1994a, Todd 1987a, White and Hannus 1983, Wood and Johnson 1978, and Zeimens 1982. Several of these variables are directly relevent to the Heron Eden assemblage.

The modification of individual elements includes indication of root damage and rodent gnawing. Rootlet-etching on the outer bone surface and penetration and damage of bones by root growth were observed. Rodent

gnawing, has been noted mainly on rib shaft fragments, but is also found on long bone fragments and phalanges. Although scavenging is likely a principal factor in the modification of the Heron Eden site faunal assemblage, no indication of that kind was noted. The analysis of carnivore attrition is presented later.

The faunal assemblage may also be modified by post-depositional movement. The appearance of calcium carbonate suggests that water, possibly groundwater, affected the Heron Eden bone bed. The presence of 19% to 26% clay in the sedimentological makeup of the paleosol and the presence of water, both groundwater and surface water (rain), suggests that the swelling and shrinking of clays contributed to post-depositional movement. Perhaps the greatest natural post-depositional movement was caused by the actions of animals. Earthworm activity is considered a significant source of sediment disturbance. Rodent burrows, many of which had filled in, were noticed throughout the excavation area. In most cases, these burrows passed through the bone bed into the underlying sediment causing some redistribution of the faunal material. Generally, the result of rodent burrowing is the homogenization of cultural deposits, obscuring discrete features and activity areas (Erlandson 1984:789).

Cultivation has reduced both the horizontal and vertical extent of the bone bed. Overall, cultivation has increased the degree of bone fragmentation and has altered the distribution of faunal material within the plowzone.

The degree of bone fragmentation and the degradation of the bone surfaces, obscured all direct evidence of cultural alteration. Although no definite cut marks were observed on the Heron Eden site bone, three

specimens, that had a generally pointed shape, were noted to exhibit evidence of polishing (Figure 5.5). Morlan suggests:

> that polishing may be interpreted as artificial if a recognizable tool form is represented or if some highly complex arrangement of polished surfaces defies other explanations. Simple devices such as bone awls can be mimicked by natural processes, and claims of artificial causes even for complex polished pieces are merely opinions of the investigator [Morlan 1984:169].

In light of these observations and given that attrition has also affected the bone surface of these specimens, the "polishing" could be attributed to natural activity.

Figure 5.5 Three specimens which exhibit possible cultural modification.

In sum, the Heron Eden site faunal assemblage is in a poor state of preservation. The majority, if not all, of the bone breakage was due to attritional processes. The bone exhibits a high degree of post-occupation weathering. A variety of processes have contributed to the attrition of the bone and to movement within the bone bed. Consequently, determining the degree to which cultural processes affected the Heron Eden faunal assemblage is severely limited.

5.3 Bone Fragmentation and Distribution

Cultivation has had a major impact on the Heron Eden bone bed. Other studies (Haselgrove 1985, Lyman and O'Brien 1987) have shown an increase in fragmentation from both the action of the cultivator and increased physical weathering. One technique for evaluating the degree of bone fragmentation in faunal assemblages is percentage completeness. This method can also be used to assess the variability of fragmentation within an assemblage. Having counted a predetermined number of portions, (Appendix A) the percentage completeness of select elements can be determined following a method outlined by Morlan (1994b). For each element,

> ... the number of portions preserved (PP) is the sum of the MNE values for a given element. Dividing the sum by the number of identified specimens (NISP) yields the average number of portions per specimen (PP/SP). Dividing this average by the number of portions defined (PD) gives the percentage completeness (%CN) [Morlan 1994b:805].

Table 5.2 shows the percentage completeness for select elements from the Heron Eden bison assemblage. The generally low values for the elements corroborate the high degree of bone fragmentation noted previously. The element completeness ranges from 3.7% for the mandible to 51.8% for the calcaneus, and results in a mean of 20.4% for the assemblage. For limb elements, which excludes the mandibles, scapulae, and innominates, the percentage completeness increases distally. In other words, metapodials and calcanei are the most complete elements with the humeri and femora are the least complete.

While assessing element completeness in a number of different sites, Todd and Rapson (1988:309) noted that "the general structure of limb bone fragmentation is remarkably similar". Metapodials are the most common complete limb bones and the humerus and femur are the most fragmentary.

This trend occurs in a number of kill sites with different degrees of completeness, from elements being recovered as complete bones to elements being fragmented and scattered (Todd and Rapson 1988:308). Thus, the general structure of limb bone fragmentation exhibited by the Heron Eden bone bed compares to that observed at other kill-butchery sites.

Table 5.2 The percentage completeness of select elements.

Element	PD	PP	NISP	PP/SP	%CN
Mandible	6	100	447	0.22	3.7%
Scapula	3	96	243	0.40	13.2%
Humerus	13	211	163	1.29	10.0%
Radius	13	211	163	1.29	10.0%
Ulna	7	191	145	1.32	18.8%
Metacarpal	8	307	88	3.49	43.6%
Innominate	10	146	144	1.01	10.1%
Femur	10	154	150	1.03	10.3%
Tibia	11	287	191	1.50	13.7%
Calcaneus	5	228	88	2.59	51.8%
Metatarsal	8	281	90	3.12	39.0%
Mean					20.4%

5.3.1 Plowzone and Paleosol Comparisons

The percentage completeness for the Heron Eden elements were derived separately for the plowzone and paleosol aggregate samples to assess the effects of cultivation on fragmentation (Table 5.3). A decrease in percentage completeness occurs for all elements in the plowzone sample resulting in a mean completeness of only 9.1 %. Accordingly, an increase in element completeness, for a mean of 23% complete, occurs with the paleosol

elements. While the mandible and calcaneus are consistently the least and most complete elements respectively, the changes in percentage completeness for the other elements is not uniform. Viewed graphically (Figure 5.6), the element percentiles show variation in the changes of element completeness between the samples. For example, the metapodials, previously among the most complete elements, are fragmented to a greater degree and now compare with the percentage completeness of the other elements in the cultivation layer.

Table 5.3 The percentage completeness of select elements from the plowzone and paleosol aggregate samples.

	Plowzone					Paleosol				
Element	PD	PP	NISP	PP/SP	%CN	PD	PP	NISP	PP/SP	%CN
Mandible	6	7	45	0.16	2.6%	6	93	402	0.23	3.9%
Scapula	3	6	17	0.35	11.8%	3	90	226	0.40	13.3%
Humerus	13	9	11	0.82	6.3%	13	202	152	1.33	10.2%
Radius	11	14	13	1.08	9.8%	11	263	113	2.33	21.2%
Ulna	7	8	17	0.47	6.7%	7	183	128	1.43	20.4%
Metacarpal	8	8	11	0.73	9.1%	8	299	77	3.88	48.5%
Innominate	10	6	9	0.67	6.7%	10	140	135	1.04	10.4%
Femur	10	6	9	0.67	6.7%	10	148	141	1.05	10.5%
Tibia	11	10	14	0.71	6.5%	11	277	177	1.56	14.2%
Calcaneus	5	17	12	1.42	28.3%	5	211	76	2.78	55.5%
Metatarsal	8	6	13	0.46	5.8%	8	275	77	3.57	44.6%
Mean					9.1%					23.0%

This differential destruction is considered a direct result of cultivation, both from the mechanical fragmentation of the elements by the cultivator and from deterioration due to exposure. This element fragmentation, therefore, alters the general structure of completeness in the

plowzone sample. Figure 5.7 graphically indicates the change in structure between the plowzone aggregate and the paleosol aggregate samples. The general pattern previously noted, an increasing distal limb completeness, occurs in the paleosol aggregate. A more erratic pattern of bone fragmentation is seen in the plowzone sample.

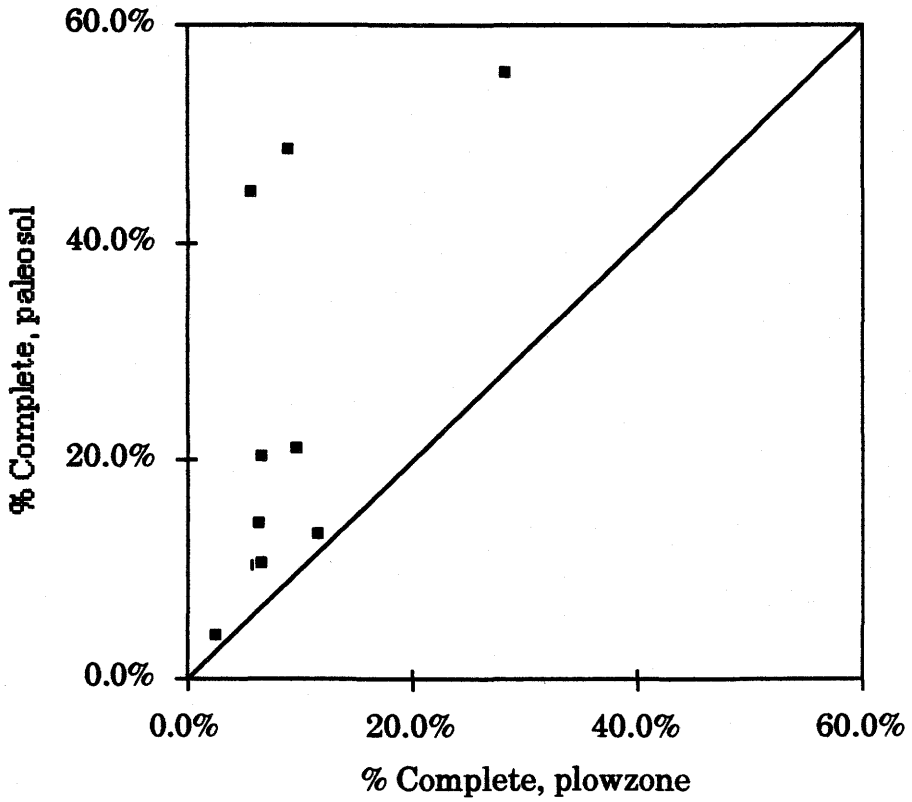
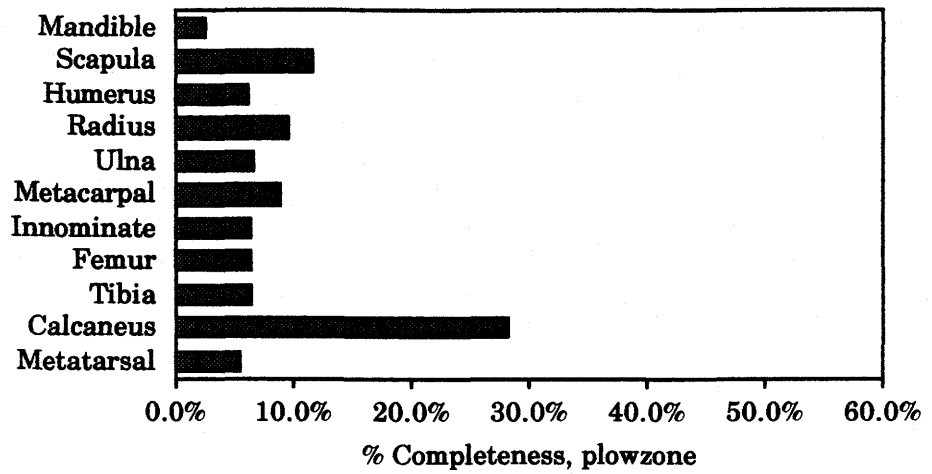
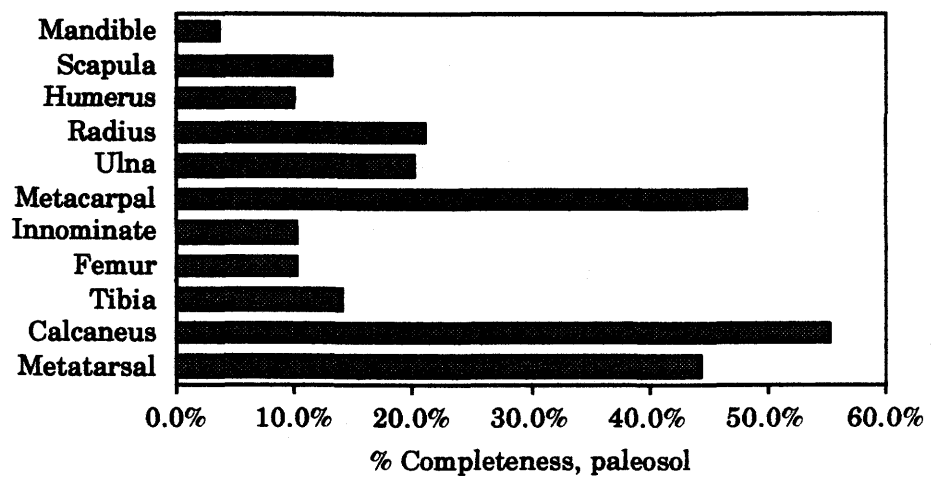


Figure 5.6 The percentage completeness of select elements from the plowzone and paleosol aggregate samples.

Since cultivation differentially affects the completeness and survivorship of the bone, biases introduced by the plowzone aggregate sample can skew the analyses based on skeletal part frequencies. Therefore, only the faunal material from the paleosol will be used in those analyses.



b)



a)

Figure 5.7 The percentage completeness of select elements from a) the paleosol aggregate and b) the plowzone aggregate samples.

5.3.2 Paleosol Distribution and Variability

The mean percentage completeness for the paleosol elements is 23.0%. It is unlikely that the degree of element completeness remains constant throughout the dispersal of faunal material in the paleosol aggregate. Therefore, percentage completeness was used to assess the degree of horizontal variability in element fragmentation. Four sample blocks were chosen to represent different areas of the bone bed (Figure 5.8). Three of the

areas (blocks A, C, and D) are located near the main concentration of faunal material (refer to Figure 4.2 and 4.3). The fourth area (block B) is outside the main excavation block where an increase in density was also noted.

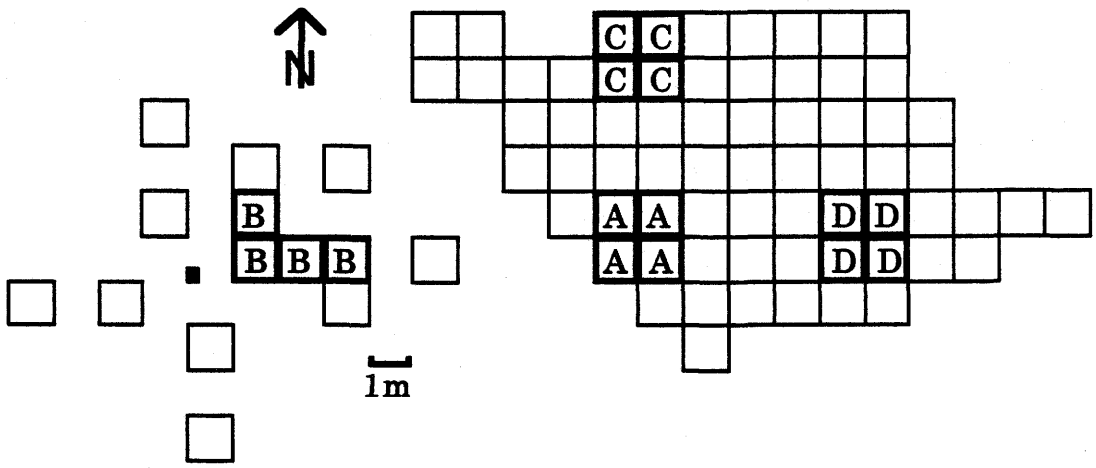


Figure 5.8 Selected areas for the assessment of fragmentation variability.

Two of the sample areas, A-block and B-block, have a mean percentage completeness that is higher, by 7% and 6% respectively, than the paleosol aggregate sample and seem comparable to each other (Table 5.4). While, C-block has a 6.5% lower mean percentage completeness, D-block is only 1% below the paleosol mean.

Figure 5.9 shows the distribution of bone by modified NISP per square meter for both the plowzone and paleosol aggregate samples. In general, the paleosol specimen frequencies tend to decrease away from an area of higher concentration in the contiguous excavation block (Figure 5.9a). A more irregular distribution is observed for the plowzone frequencies with the highest specimen counts in western portion of the excavated area where the impact of cultivation was greater (Figure 5.9b).

Table 5.4 Percentage completeness of select elements in four sample areas.

Element	A-block					B-block				
	NISP	PD	PP	PP/SP	%CN	NISP	PD	PP	PP/SP	%CN
Mandible	10	6	4	0.40	6.7	3	6	0	-	-
Scapula	5	3	3	0.60	20.0	6	3	7	1.17	38.9
Humerus	6	13	9	1.50	11.5	11	13	16	1.45	11.2
Radius	3	11	4	1.33	12.1	0	11	0	-	-
Ulna	3	7	6	2.00	28.6	5	7	8	1.60	22.9
Metacarpal	0	8	0	-	-	3	8	11	3.67	45.8
Innominate	10	10	9	0.90	9.0	9	10	9	1.00	10.0
Femur	9	10	10	1.11	11.1	8	10	10	1.25	12.5
Tibia	18	11	29	1.61	14.6	11	11	8	0.73	6.6
Calcaneus	4	5	17	4.25	85.0	7	5	20	2.86	57.1
Metatarsal	2	8	15	7.50	93.8	3	8	12	4.00	50.0
Mean					29.2					28.3

Element	C-block					D-block				
	NISP	PD	PP	PP/SP	%CN	NISP	PD	PP	PP/SP	%CN
Mandible	14	6	3	0.21	3.6	14	6	7	0.50	8.3
Scapula	6	3	5	0.83	27.8	4	3	2	0.50	16.7
Humerus	3	13	3	1.00	7.7	5	13	4	0.80	6.2
Radius	2	11	3	1.50	13.6	5	11	14	2.80	25.5
Ulna	0	7	0	-	-	5	7	5	1.00	14.3
Metacarpal	3	8	5	1.67	20.8	4	8	14	3.50	43.8
Innominate	4	10	4	1.00	10.0	3	10	3	1.00	10.0
Femur	11	10	8	0.73	7.3	4	10	4	1.00	10.0
Tibia	4	11	3	0.75	6.8	1	11	1	1.00	9.1
Calcaneus	4	5	11	2.75	55.0	4	5	13	3.25	65.0
Metatarsal	3	8	3	1.00	12.5	5	8	14	2.80	35.0
Mean					16.5					22.2

A combination of observations can be made from the element percentage completeness in the sample blocks. These include general observations on the condition of the faunal material and the frequency of faunal specimens in the plowzone and paleosol aggregate samples.

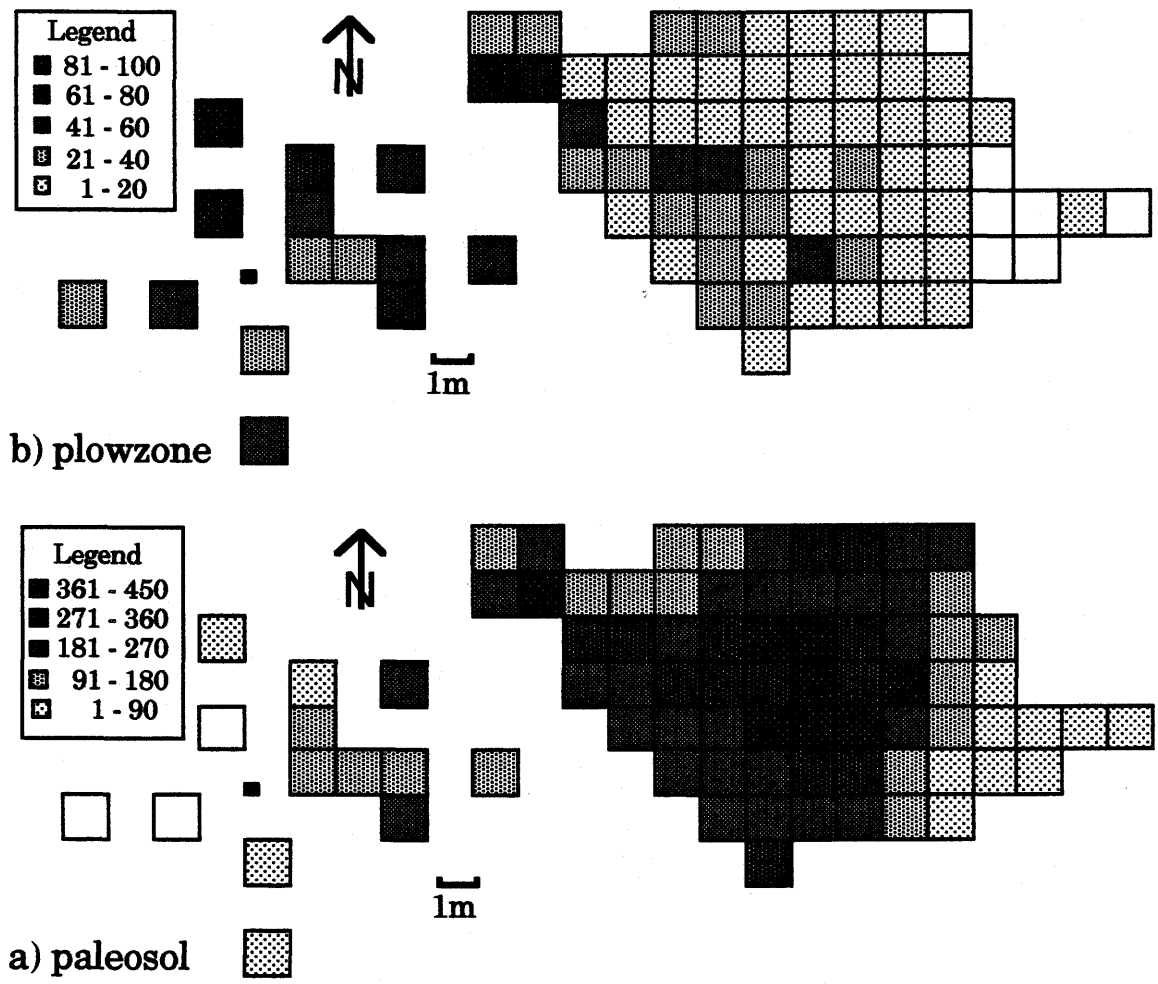


Figure 5.9 The distribution of modified NISP's for the a) paleosol aggregate and b) plowzone aggregate samples.

Proceeding west from the area of maximum density in the contiguous excavation block, including sample blocks A and B, a zone of more complete elements is present. In this zone, the frequency of faunal specimens decreases as the paleosol progressively thins. This decrease is probably due to the increasing impact of cultivation, not a reduction in the original density of faunal material in the paleosol.

The bone from the northeastern portion of the excavation block, including sample block C, has the lowest percentage complete values. Considering the increase in weathering and dry bone cracking noted for this area, the higher incidence of fragmentation is likely due to increased attrition. Although it is likely that the bone has been affected by both pre-burial and post-burial weathering, the condition of the bone in this area suggests extended pre-deposition exposure or likewise, multiple burial and re-exposure events.

The northeastern and eastern portion of the paleosol is intact and extends beyond the excavation boundaries. The faunal material is located farther below the surface and to a large extent has not been affected by cultivation. Sample block D is included in this area. Thus, the rapid decrease in the frequency of faunal specimens here is considered to result from being on the margin of the bone bed. Much of the bone exhibits extensive exfoliation of the cortical surface and a high incidence of fragmentation. In comparison to the condition of the bone in other areas of the site, post-burial attrition is considered to be the dominant form of weathering.

In sum, a variety of attritional processes have affected the bone bed at the Heron Eden site. The extent to which both pre-burial and post-burial weathering have influenced the completeness of the bone in the paleosol is variable. Pre-burial weathering is viewed as the dominant variable in some areas while, in others, post-burial attrition is the primary agent observed. However, in the majority of the site area, no primary agent of attrition can be isolated; both have contributed in varying degrees.

Cultivation has altered the paleosol bone specimen frequencies, to an increasing extent westward of the central area of specimen density. The

paleosol is only present eastward of the faunal concentration and a rapid decrease in bone density indicates the bone bed margin. As previously noted, to the north, west, and south a combination of cultivation and sedimentary deflation has removed the paleosol and associated faunal material.

5.4 Skeletal Part Frequencies

One of the basic classes of information included in the analyses of faunal remains is the counts of skeletal element frequencies (Binford 1978, Grayson 1984, Lyman 1994a, Speth 1983). How these frequencies differ from what is expected in a complete skeleton provides the basis for interpreting which skeletal parts were removed by either cultural fragmentation and transport, scavenging, density-mediated attrition, or combinations of the above. Typically, the evaluation of skeletal part frequencies includes inferences regarding cultural behavior, carnivore attrition, and post-occupational processes.

Table 5.5 shows the various skeletal counts employed on the Heron Eden paleosol faunal assemblage. The total and plowzone MNE counts are only included for completeness. Percent MAU values, which reflect the standardized adjusted element counts (see Chapter 3), are used to illustrate the presence, and absence, of skeletal elements. The %MAU's range from a low of 1.2% for the sternum to 100% for mandibles. When utilized collectively, the MAU's account for the presence of approximately 53.6% of the possible number of skeletal remains expected in the paleosol level at the site. Figure 5.10 illustrates this graphically.

The better represented elements include the mandible, carpals and tarsals, and phalanges. The mandible is the most represented element based on counts of the third molar. All of the tooth counts are greater than the

Table 5.5 Element counts at the Heron Eden site.

Group Element	Total MNE	Plowzone MNE	Paleosol MNE	 MAU	 %MAU
Axial elements					
Cranium	43	8	35	17.5	53.8
Mandible	25	2	23	11.5	-
* Incisor/Canines	133	6	127	15.9	-
* Premolar	109	12	97	16.2	-
* M1	48	4	44	22.0	-
* M2	54	4	50	25.0	-
* M3	72	7	65	32.5	100.0
Hyoids	11	0	11	5.5	16.9
Sternum	2	0	2	0.4	1.2
Rib	146	5	141	5.4	16.7
Atlas	17	2	15	15.0	46.2
Axis	19	1	17	17.0	52.3
Cervical	62	1	61	12.2	37.5
Thoracic	131	3	128	9.1	28.1
Lumbar	91	1	90	18.0	55.4
Sacral	28	0	28	5.6	17.2
Caudal	42	2	40	4.0	12.3
Forelimb					
Scapula	46	3	43	21.5	66.2
Humerus, prox.	24	1	23	11.5	35.4
Humerus, dist.	41	3	38	19.0	58.5
Radius, prox	33	2	31	15.5	47.7
Radius, dist.	40	1	39	19.5	60.0
Ulna, prox.	42	4	38	19.0	58.5
Ulna, dist.	32	1	31	15.5	47.7
Radial carpal	62	11	51	25.5	78.5
Internal carpal	58	8	50	25.0	76.9
Ulnar carpal	54	6	48	24.0	73.8
Accessory carpal	40	5	35	17.5	53.8
Carpal 2+3	57	11	46	23.0	70.8
Carpal 4	65	9	56	28.0	86.2
5th Metacarpal	34	5	29	14.5	44.6
Metacarpal, prox.	40	2	38	19.0	58.5
Metacarpal, dist.	44	1	43	21.5	66.2

continued

Table 5.5 (continued) Element counts at the Heron Eden site

Group / Element	Total MNE	Plowzone MNE	Paleosol MNE	Paleosol MAU	Paleosol %MAU
Hindlimb					
Innominate	42	1	41	20.5	63.1
Femur, prox.	42	3	39	19.5	60.0
Femur, dist.	24	1	23	11.5	35.4
Patella	34	3	31	15.5	47.7
Tibia, prox.	31	1	30	15.0	46.2
Tibia, dist.	37	4	33	16.5	50.8
Calcaneus	49	3	46	23.0	70.8
Astragalus	50	5	45	22.5	69.2
Tarsal C+4	61	10	51	25.5	78.5
Tarsal 2+3	63	6	57	28.5	87.7
Tarsal 1	19	2	17	8.5	26.2
Lat Malleolus	49	7	42	21.0	64.6
2nd Metatarsal	22	4	18	9.0	27.7
Metatarsal, prox.	39	1	38	19.0	58.5
Metatarsal, dist.	41	1	40	20.0	61.5
Other Appendicular					
1st Phalanx	232	17	215	26.9	82.7
2nd Phalanx	218	21	197	24.6	75.8
3rd Phalanx	179	4	175	21.9	67.3
Sesamoids, slat.	149	24	125	15.6	48.1
Sesamoids, smed.	160	25	135	16.9	51.9
Sesamoids, infer.	85	6	79	9.9	30.4

*Separate counts of mandibular tooth portions. Only highest count used in the calculation of %MAU.

counts based on mandibular bone portions. The least represented elements include hyoids, ribs, sternebrae, and caudal vertebrae. Generally, the appendicular elements are better represented than the axial. Thus, some processes of attrition - cultural, natural, or a combination of both - are selectively removing more axial elements than appendicular from the Heron Eden site kill-butchery bison assemblage.

Element	%MAU
Mandible (M3)	100.0
Tarsal 2+3	87.7
Carpal 4	86.2
1st phalanx	82.7
Radial carpal	78.5
Tarsal C+4	78.5
Internal carpal	76.9
2nd phalanx	75.8
Ulnal carpal	73.8
Carpal 2+3	70.8
Calcaneus	70.8
Astragalus	69.2
3rd phalanx	67.3
Scapula	66.2
Metacarpal, dist.	66.2
Lat. malleolus	64.6
Innominate	63.1
Metatarsal, dist.	61.5
Radius, dist.	60.0
Femur, prox.	60.0
Humerus, dist.	58.5
Ulna, prox.	58.5
Metacarpal, prox.	58.5
Metatarsal, prox.	58.5
Lumbar	55.4
Cranium	53.8
Accessory carpal	53.8
Axis	52.3
Sesamoid, smed.	51.9
Tibia, dist.	50.8
Sesamoid, slat.	48.1
Radius, prox.	47.7
Ulna, dist.	47.7
Patella	47.7
Atlas	46.2
Tibia, prox.	46.2
5th metacarp.	44.6
Cervical	37.5
Humerus, prox.	35.4
Femur, dist.	35.4
Sesamoid, infer.	30.4
Thoracic	28.1
2nd metatars.	27.7
Tarsal 1	26.2
Sacrum	17.2
Hyoids	16.9
Rib	16.7
Caudal	12.3
Sternum	1.2

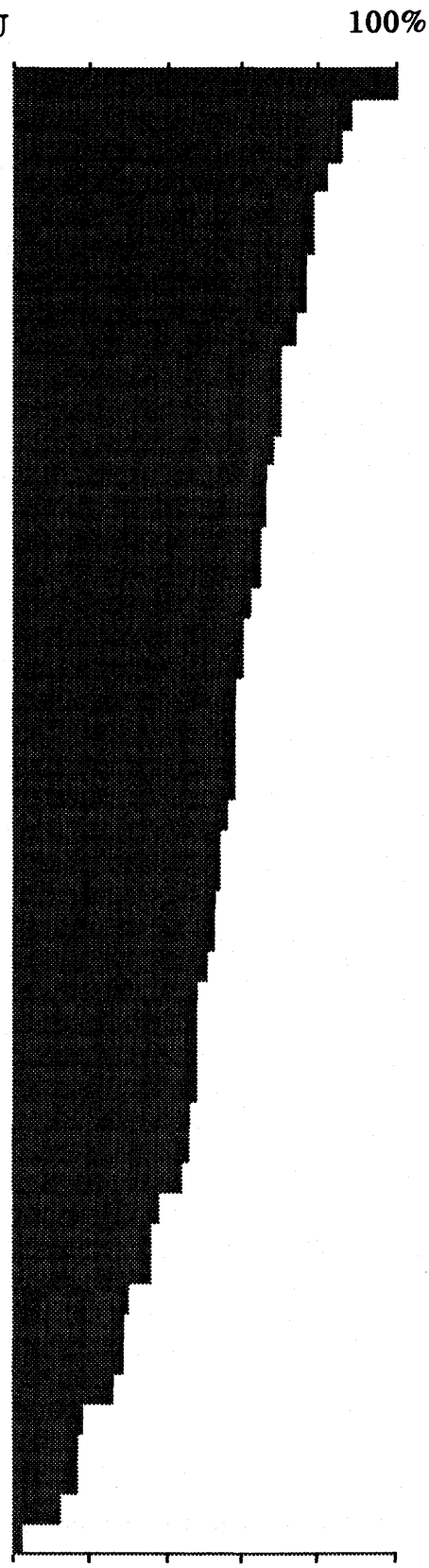


Figure 5.10 %MAU for the Heron Eden site bison elements.

5.4.1 Utility and Density

The economic utility, or the human utilization and transport, of skeletal parts has become a standard frame of reference in interpreting the content of faunal assemblages (Binford 1978, 1981; Brink and Dawe 1989; Emerson 1990; Frison 1970, 1974; Jones and Metcalfe 1988; Kehoe and Kehoe 1960; Lyman 1985, 1992; Marshall and Pilgram 1991, Perkins and Daly 1968; Speth 1983, Wheat 1972; White 1954, 1955). Binford (1978:77-81) describes a "reverse utility strategy" when anatomical parts of high utility are represented by low frequencies and parts of low utility are represented by high frequencies. Binford (1978: Table 2.7) derived the modified general utility index (MGUI) , a measure of the economic utility of various skeletal elements adjusted for transport decisions, for both caribou and sheep. Traditionally, the caribou model has been used on bison assemblages. More recently, Emerson (1990) has derived utility indices for modern bison. Emerson generated several measures of carcass utility in the formation of several models to account for differences in herd structure (Emerson 1990:616-625). The averaged model of general economic utility is used here. The standardized modified average total products model ((S) MAVGTP) is an averaged index measure of the caloric yields of the products associated with each carcass unit modified by transport decisions (Emerson 1990: Table 8.6).

However, Lyman (1992: 9) notes a generally consistent inverse relationship between the volume density of skeletal parts and the utility of those parts. In other words, there is potential, in assemblages that have undergone some form of density-mediated destruction, for skeletal part frequencies to be "suggestive" of a reverse-utility strategy (Lyman 1992:19). Thus differential destruction, due to the structural density of skeletal parts,

must also be considered (Grayson 1989; Kreutzer 1992; Lyman 1984, 1985; Marean and Spencer 1991). Following the work done by Lyman (1984) on deer bone densities, Kreutzer (1992: Table 2) derives volume mineral bone densities for bison skeletal parts. Generally, density-mediated attrition tends to be more visible in assemblage counts than utility because density-mediated destruction includes many taphonomic processes such as scavenging, fluvial transport, and weathering, whereas utility intends to monitor only human utilization and transport (Lyman 1993:333). The prevalent method for studying the various relationships between skeletal part frequencies and both consumption utility and bone mineral density is a rank order correlation. Spearman's Rank Correlation Coefficient (r_S) is used (Ebdon 1985:97). In this thesis, r denotes Spearman's rho, P indicates probability, and N is the number of ranks.

The Heron Eden paleosol element frequencies have a significant negative correlation with the utility indices derived by Emerson (1990) (Table 5.6; $r = -0.36$, $P < 0.05$, $N = 25$). Figure 5.11 graphically shows this negative relationship between utility and %MAU which is suggestive of a reverse-utility curve. In general, a negative relationship is noted for both the axial and appendicular elements.

Examination of the relationship between the paleosol element frequencies and bone volume density, as measured by Kreutzer (1992), result in a significant positive correlation (Table 5.7; $r = 0.43$, $P < 0.01$, $N = 37$). Figure 5.12 shows the positive relationship between density and %MAU. Overall, a positive relationship is noted for both the axial and appendicular elements. Therefore, the Heron Eden site paleosol element frequencies, while having a significant negative correlation with utility, also have a significant positive correlation with bone density. This represents

Lyman's (1994a:264) Class 1 assemblage, which indicates that either differential economic utilization and transport or differential density mediated destruction, or both, have affected the paleosol aggregate.

Table 5.6 Rank order correlation between the Heron Eden site paleosol %MAU and a modified, averaged total products utility model*.

Element	Paleosol %MAU	MAU Rank	(S)MAVGTP Rank	Emerson (S)MAVGTP	GTP Portion
Cranium	53.8	12	11	14.2	SKWOT
Atlas	46.2	8.5	5	6.4	ATLAS
Axis	52.3	11	8	7.8	AXIS
Cervical	37.5	7	20	56.6	C3C7
Thoracic	28.1	4	24	84.7	THOR
Lumbar	55.4	13	23	82.9	LUMB
Caudal	12.3	2	1	1.5	CAUD
Rib	16.7	3	25	100	RIBS
Sternum	1.2	1	18	52.9	STER
Scapula	66.2	22.5	15.5	31.6	SCAP
Humerus, prox.	35.4	5.5	15.5	31.6	PHUM
Humerus, dist.	58.5	15.5	13	25.1	DHUM
Ulna, prox.	58.5	15.5	12	16.5	PRUL
Radius, dist	60.0	18.5	9	12.1	DRUL
Carpal 4	86.2	24	6	6.6	CARP
Metacarpal, prox.	58.5	15.5	3	3.9	PMTC
Metacarpal. dist	66.2	22.5	2	2.6	DMTC
Innominate	63.1	21	19	54.7	SPEL
Femur, prox.	60.0	18.5	21.5	69.4	PFEM
Femur, dist.	35.4	5.5	21.5	69.4	DFEM
Tibia, prox.	46.2	8.5	17	40.8	PTIB
Tibia, dist.	50.8	10	14	25.5	DTIB
Tarsal 2+3	87.7	25	10	13.6	TARS
Metatarsal, prox.	58.5	15.5	7	7.5	PMTT
Metatarsal, dist.	61.5	20	4	4.5	DMTT

* Utility model values from Emerson (1990: Table 8.6).
$r = -0.36$, $p < 0.05$, $N = 25$.

Grayson (1989:647) proposes that assemblages produced by density mediated destruction should result in a significant positive correlation between %MAU and bone density and an insignificant correlation between %MAU and utility. Conversely, element frequencies produced by human

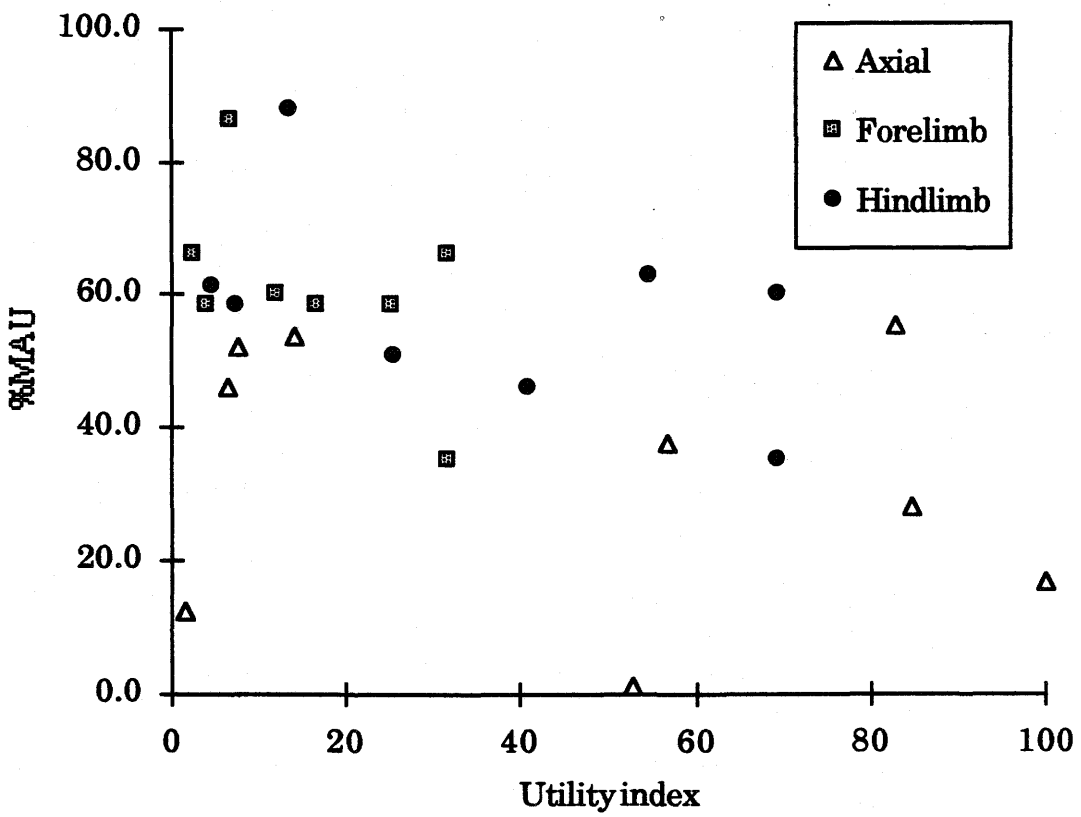


Figure 5.11 Comparison of the paleosol %MAU and Emerson's (1990: Table 8.6) modified, averaged total products utility model.

economic utility strategies should result in a significant negative correlation between %MAU and utility and an insignificant correlation between %MAU and volume density (Grayson 1989:647). But in the case of a Class 1 assemblage, other analyses must be included to determine if the element frequencies are the result of cultural utility, density-mediated attrition, or a combination of these processes. These include the comparison of economic utility and bone mineral density with different anatomical groups of skeletal element frequencies and assessing the effect of carnivore attrition on the paleosol assemblage.

Table 5.7 Rank order correlation between the Heron Eden site paleosol %MAU and volume density measured at corresponding scan sites*.

Element	Paleosol %MAU	MAU Rank	V.D. Rank	Volume Density	Scan Site
Mandible	35.4	5	34	0.61	DN2
Atlas	46.2	8.5	8.5	0.34	AT3
Axis	52.3	13	35	0.65	AX1
Cervical	37.5	7	13	0.37	CE1
Thoracic	28.1	3	17.5	0.42	TH1
Lumbar	55.4	14	5.5	0.31	LU1
Sacral	17.2	2	3.5	0.27	SC1
Rib	16.7	1	3.5	0.27	RI1
Scapula	66.2	24.5	25.5	0.5	SP1
Humerus, prox.	35.4	5	1	0.24	HU1
Humerus, dist.	58.5	16.5	14	0.38	HU5
Radius, prox.	47.7	10.5	22.5	0.48	RA1
Radius, dist.	60.0	19.5	11	0.35	RA5
Ulna, prox.	58.5	16.5	8.5	0.34	UL1
Ulna, dist.	47.7	10.5	11	0.35	RA5
Radial carpal	78.5	33.5	17.5	0.42	SCAPH
Internal carpal	76.9	32	11	0.35	LUNA
Ulnar carpal	73.8	30	19	0.43	CUNEI
Carpal 2+3	70.8	28.5	28.5	0.52	TRAPM
Carpal 4	86.2	36	20	0.44	UNCIF
Metacarpal, prox.	58.5	16.5	32	0.59	MC1
Metacarpal, dist.	66.2	24.5	33	0.6	MC4
Innominate	63.1	22	30	0.53	AC1
Femur, prox.	60.0	19.5	5.5	0.31	FE1
Femur, dist.	35.4	5	2	0.26	FE6
Tibia, prox.	46.2	8.5	15.5	0.41	TI1
Tibia, dist	50.8	12	15.5	0.41	TI5
Calcaneus	70.8	28.5	24	0.49	CA3
Astragalus	69.2	27	36	0.72	AS1
Tarsal C+4	78.5	33.5	37	0.77	NC3
Tarsal 2+3	87.7	37	25.5	0.5	2&3C
Lat Malleolus	64.6	23	31	0.56	LATM
Metatarsal, prox.	58.5	16.5	28.5	0.52	MR1
Metatarsal, dist	61.5	21	27	0.51	MR4
1st Phalanx	82.7	35	22.5	0.48	P13
2nd Phalanx	75.8	31	21	0.46	P23
3rd Phalanx	67.3	26	7	0.32	P31

* Volume density values from Kreutzer (1992: Table 2).
$r = 0.43$, $p < 0.01$, $N = 37$.

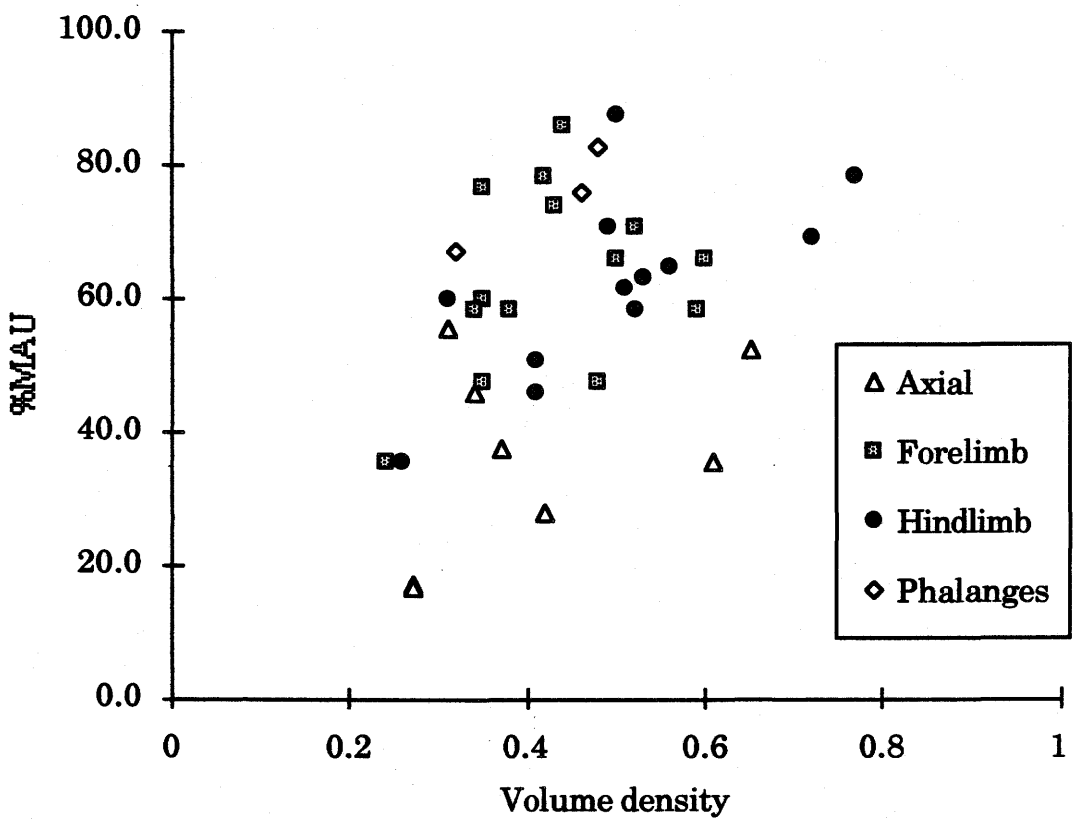


Figure 5.12 Comparison of the paleosol %MAU and Kreutzer's (1992: Table 2) volume density measured at corresponding scan sites.

5.4.2 Counting Units

How a particular skeletal part is counted to determine its frequency is important because that counting unit is used in all correlations (Lyman 1994a:263-275). The element frequencies from the Heron Eden site were derived by counting discrete anatomical portions (Morlan 1994b). The most abundant portion provides the MNE for the particular skeletal unit, and its anatomical frequency is used to calculate MAU (also see Chapter 3 and Appendix A). By counting these discrete portions one can generate the frequency data appropriate for the frame of reference being used.

The element frequencies chosen for correlation with the utility indices were based on the anatomical unit which derived that particular utility measurement. For example, the utility units PRUL and DRUL include the proximal and distal radius/ulna region, thus the highest proximal and distal MNE's in the paleosol sample are from the proximal ulna and the distal radius (Table 5.6). For correlations with bone density, the appropriate scan sites are used for the anatomical portion which derived the maximum MNE's of each skeletal unit. For example, the maximum count for the axis is from the anterior portion, thus AX1 scan site is used; the maximum count for the distal metacarpal is the anterior and posterior foramen of the distal shaft, so MC4 scan site is used, and so on (see Table 5.7).

The previous correlations considered all of the skeletal element frequencies together. Based on ethnographic data, Binford (1978:60) concluded that human utilization can result in different degrees of anatomical dismemberment. " The animal is divided into sets of anatomical parts " and " decisions for additional partitioning are made independently for sub-components of each of these sets" (Binford 1978:60). Thus, select anatomical regions should be correlated with both bone density and economic utility indices to measure variation in how they are represented (Lyman 1994a:266, Morlan 1994b:765, and Stiner 1991b:463).

Table 5.8 presents rank order correlations between paleosol %MAU and both economic utility and bone density for three select anatomical regions; axial, forelimb, and hindlimb (refer to Tables 5.6 and 5.7). The element frequencies for all skeletal portions are negatively correlated with economic utility and positively correlated with bone density. The only significant correlation is between the hindlimb element frequencies and bone density ($r = 0.64$, $p > 0.025, <0.01$, $N = 12$). Additionally, there is almost

an absence of correlation between the axial skeletal portion and utility (r = -0.017, p = n.s., N = 9).

Table 5.8 Correlations between paleosol element frequencies and a bison utility model and volume density for three skeletal portions*.

Element group	Utility			Volume density		
	r	p	N	r	p	N
Axial elements	-0.017	n.s.	9	0.423	n.s.	8
Forelimb elements	-0.351	n.s.	8	0.305	n.s.	14
Hindlimb elements	-0.351	n.s.	8	0.564	<0.025, >0.01	12

* Utility index is from Emerson (1990:Table 8.6), a modified, averaged total products model; volume density after Kreutzer (1992: Table 2).

Another group of elements, consisting only of long bones from the forelimb and hindlimb, is considered (Table 5.9). The proximal and distal portions of the humerus, radius (ulna), metacarpal, femur, tibia, and metatarsal, are compared to both utility and bone density (refer to Tables 5.6 and 5.7 for the appropriate data). The proximal ulna is utilized, rather than the proximal radius, when the utility correlation is considered for the reasons cited previously. Again, a negligible correlation is noted with utility, but there is a significant positive correlation between long bone frequencies and bone density (r = 0.51, p > 0..5, < 0.025, N = 12).

Similarly, density-mediated attrition operates directly on anatomical elements and indirectly on whole skeletons (Morlan 1994b:804). Rapson (1990:237 as cited in Lyman 1992:20) suggests that "fragmentary MNE's" of long bone portions can provide insight for patterns of skeletal part

frequencies. Morlan (1994b) offers a comparative method to assess the relationship between element portion frequencies and bone density.

Table 5.9 Correlations between long bone proximal and distal portions and a utility model and volume density*.

Utility			Volume density		
r	p	N	r	p	N
-0.087	n.s.	12	0.511	<0.05, >0.025	12

* Utility index from Emerson (1990: Table 8.6); volume density after Kreutzer (1992: Table 2).

Table 5.10 presents the paleosol bone portion frequencies and volume density scan sites for the larger skeletal elements. If more than one MNE was counted for each scan site, only the maximum is presented (refer to Appendix A). The scapula is not included because only three bone portions, which refer to one scan site, were counted. Only five mandible bone counts are included because no bone counts were taken of the tooth row area where three of the bone density scan sites are located. For the Heron Eden site, no significant correlations occur (Table 5.11). In fact, the correlations for the radius and tibia are negative, while the remainder are positive.

Lyman and O'Brien (1987:497) suggest that there is a minimum identifiable size for bone fragments, and that this size " will vary from taxon to taxon and from skeletal element to skeletal element within a skeleton ". Accordingly, the degree to which a particular fragment is identifiable depends on the presence of a diagnostic zone (Lyman and O'Brien 1987:496). In this analysis, the identification of bone portions on individual elements utilizes both discrete features and large essentially featureless areas,

recognizable by their general conformation, referred to as zones (following Morlan 1994b). Typically, the frequency of the proximal and distal ends of long bones is determined from counting discrete features, while the denser long bone shaft portions consists of zones. Thus, when fragmented, the shafts are more difficult to recognize. Consequently, for the Heron Eden elements, the lack of significant correlations between element portions and density and the negative correlations could be due to the high degre of bone fragmentation.

Table 5.10 Rank order correlation between paleosol bone portion frequencies and volume density measured at corresponding scan sites*.

Element	Portion	MNE	Paleosol MAU	%MAU	%MAU Rank	V.D. Rank	Volume Density	Scan site
Mandible	Coronoid Process	17	8.5	26.2	3	4.5	0.79	DN8
	Articular Condyle	19	9.5	29.2	4	4.5	0.79	DN7
	Angle	9	4.5	13.8	1	2	0.57	DN6
	Diastema	23	11.5	35.4	5	3	0.61	DN2
	Symphysis	14	7	21.5	2	1	0.53	DN1
Humerus	Head	23	11.5	35.4	3	1	0.24	HU1
	Prox Shaft	8	4	12.3	1	2	0.25	HU2
	Post-lat Foramen	18	9	27.7	2	4	0.45	HU3
	Coronoid Fossa	37	18.5	56.9	4	5	0.48	HU4
	Medial Condyle	38	19	58.5	5	3	0.38	HU5
Radius	Med Glen Cavity	31	15.5	47.7	4	3	0.48	RA1
	Radial Tuberosity	28	14	43.1	3	4	0.56	RA2
	Mid-Post Shaft	21	10.5	32.3	2	5	0.62	RA3
	Dist-Ant Shaft	16	8	24.6	1	2	0.42	RA4
	Internal Carp. facet	39	19.5	60.0	5	1	0.35	RA5
Ulna	Olecranon Process	26	13	40.0	3	1	0.34	UL1
	Anconeal Process	38	19	58.5	5	5	0.69	UL2
	Prox Shaft	16	8	24.6	1	3	0.56	RA2
	Mid-Shaft	20	10	30.8	2	4	0.62	RA3
	Styloid Process	31	15.5	47.7	4	2	0.35	RA5

continued

Table 5.10 (continued) Rank order correlation between paleosol bone portion frequencies and volume density measured at corresponding scan sites.

Element	Portion	MNE	Paleosol MAU	%MAU	%MAU Rank	V.D. Rank	Volume Density	Scan site
Metacarpal	Medial Condyle	35	17.5	53.8	1	1	0.53	MC6
	Anterior Shaft	36	18	55.4	2	4	0.63	MC2
	Anterior Foramen	43	21.5	66.2	4	3	0.60	MC4
	Carpal 4 Facet	38	19	58.5	3	2	0.59	MC1
Innominate	Ilium blade	9	4.5	13.8	4	2	0.22	IL1
	Ilium Shaft	8	4	12.3	3	5	0.52	IL2
	Acetab-Ilium	41	20.5	63.1	7	6	0.53	AC1
	Ishium Shaft	17	8.5	26.2	6	4	0.50	IS1
	Ischial Tuber	2	1	3.1	2	1	0.19	IS2
	Pubis Shaft	11	5.5	16.9	5	7	0.55	PU1
	Pubic Symphysis	1	0.5	1.5	1	3	0.39	PU2
Femur								
	Head	39	19.5	60.0	6	3	0.31	FE1
	Greater Trochanter	1	0.5	1.5	1	1	0.22	FE7
	Lesser Trochanter	10	5	15.4	2	4	0.34	FE3
	Anterior Shaft	14	7	21.5	3	6	0.45	FE4
	Supracond Fossa	19	9.5	29.2	4	5	0.36	FE5
	Medial Condyle	23	11.5	35.4	5	2	0.26	FE6
Tibia								
	Lateral Condyle	30	15	46.2	3	1.5	0.41	TI1
	Post-lat Foramen	23	11.5	35.4	1	4	0.58	TI2
	Prox-Post Shaft	25	12.5	38.5	2	5	0.76	TI3
	Dist-Post Shaft	33	16.5	50.8	4.5	3	0.44	TI4
	Medial Groove	33	16.5	50.8	4.5	1.5	0.41	TI5
Calcaneus								
	Proximal Epiph.	37	18.5	56.9	1	1	0.46	CA1
	Tuber Calcis	44	22	67.7	2.5	4	0.80	CA2
	Sustentaculum	46	23	70.8	4	2	0.49	CA3
	Tarsal C+4 Facet	44	22	67.7	2.5	3	0.66	CA4
Metatarsal								
	Tarsal C+4 Facet	38	19	58.5	2.5	3	0.52	MR1
	Anterior Shaft	38	19	58.5	2.5	4	0.59	MR2
	Anterior Foramen	40	20	61.5	4	2	0.51	MR4
	Lateral Condyle	28	14	43.1	1	1	0.48	MR6

*Volume density values at corresponding scan sites from Kreutzer (1992: Table 2).

Table 5.11 Correlation between paleosol element %MAU and volume density for select elements.

Element	Paleosol		
	N	r	P
Mandible	5	0.575	n.s.
Scapula	-	-	-
Humerus	5	0.300	n.s.
Radius	5	-0.400	n.s.
Ulna	5	0.200	n.s.
Metacarpal	4	0.400	n.s.
Innominate	7	0.607	n.s.
Femur	6	0.086	n.s.
Tibia	5	-0.575	n.s.
Calcaneus	4	0.350	n.s.
Metatarsal	4	0.350	n.s.

In sum, there is a significant positive correlation between the paleosol element frequencies and bone density when all the skeletal elements are included. The correlations remain positive when the elements are separated into anatomical groupings, but only the hindlimb comparison is significant. The proximal and distal portions of long bones also correlate significantly when considered as a group. When individual elements are considered, none of the bone portion frequencies correlate significantly with density.

There is a significant negative correlation between element frequency and economic utility when all elements are considered. No significant correlations are observed when the groupings of elements are considered nor when the proximal and distal ends of long bones are compared as a group. Since bone density has a significant negative correlation with economic utility, the relationship between the paleosol element counts and utility could be the result of density-mediated element destruction.

5.4.3 Carnivore Modification

The underrepresentation of immature animals at the Heron Eden site has been shown to be largely the result of the density-mediated attrition of less dense elements. Munson (1991:139) suggests that the primary cause for the differential attrition rates in a number of archaeological faunal assemblages is the pre-depositional selective scavenging activities of dogs.

Many studies on the effect of carnivore attrition on skeletal element frequency have been completed (Binford 1981; Blumenschine 1988; Marean 1991; Marean and Spencer 1991; Marean et al. 1992; Munson 1991). Carnivore activity is usually discussed in terms of bone modification attributes such as ragged edge chewing, pitting, punctures, striations, gouge marks, scratches. furrows, and so on (Behrensmeyer et al. 1989:105-117, Binford 1981:35-86, Hill 1989:174-175, Lyman 1994a:206-212, Marshall 1989:18-19). No such direct evidence for carnivore attrition (tooth scoring, furrows, punctures) is noted for the Heron Eden faunal assemblage. Although the observed degree of bone weathering and deterioration could obscure indications of carnivore activity, carnivore tooth marks may not always be present to signify carnivore attrition. Dogs (*Canis familiaris)* have been shown to gnaw and redistribute bones and not leave any visible gnawing marks (Kent 1981).

Todd and Rapson (1988:309-313) assess the degree of carnivore modification to faunal assemblages based on patterns of differential destruction of long bone ends. They suggest a number of methods to assess the degree of long bone fragmentation to enhance intersite comparisons and recognize patterns of differential destruction. Percentage complete and percentage difference measures are utilized in this study. Percentage complete is concerned with the number of complete elements versus the

maximum proximal or distal end count. It is utilized for inter-site comparisons. This is a different method of assessing element completeness than that presented previously (see Table 5.2).

The percentage difference, a measure of long bone fragmentation, is used to recognize patterns in the differential destruction of long bone ends (Todd and Rapson 1988:309). This provides a technique to identify elements that have had one end preferentially destroyed. Binford (1981:217-221) noted a significant difference in survival potential between the proximal and distal ends of the humerus and tibia. Since both elements are among the most commonly damaged by gnawing, plots of their percentage difference can indicate the intensity of carnivore damage.

The percentage complete and percentage difference values were calculated for the Heron Eden paleosol sample (Table 5.12). As previously recognized for the Heron Eden long bone percentage completeness, a similar structure in limb bone fragmentation occurs with the humerus and the femur being the most fragmented and the metapodials the most complete elements. A linear relationship is noted when the Heron Eden site percentage completeness values are plotted against those of the Horner site (Figure 5.13). Even though the fragmentation levels are extremely different at these two sites, a strong linear relationship is observed.

Larger percentage difference values suggest greater differential destruction of the long bone ends. Similarly, small percentage differences suggest that little preferential selection or destruction by cultural or natural processes has occurred. In general, the percentage difference values at the Heron Eden site are low and represent limited differential destruction. Even when the humerus and tibia, with the large difference in survival potential,

Table 5.12 Percentage complete and percentage difference values for long bones from the Heron Eden site paleosol aggregate.

	Number Complete (I)	Proximal End (II)	Distal End (III)	Max. Number (IV)	%Complete	%Difference
Humerus	0	23	38	38	0.00	24.59
Radius	5	26	34	39	12.82	11.43
Metacarpal	23	15	20	43	53.49	6.17
Femur	0	39	23	39	0.00	25.81
Tibia	4	27	29	33	12.12	3.13
Metatarsal	23	15	17	40	57.50	2.56

*Percentage complete = $\frac{\text{Column I x 100}}{\text{Column IV}}$

*Percentage difference= $\frac{|([\text{Col. I + col. II}]-[\text{col. I + col. III}]) \text{ x } 100|}{(\text{Col. I + col. II}) + (\text{col. I + col. III})}$

*Formulas taken from Todd and Rapson (1988: Table 1).

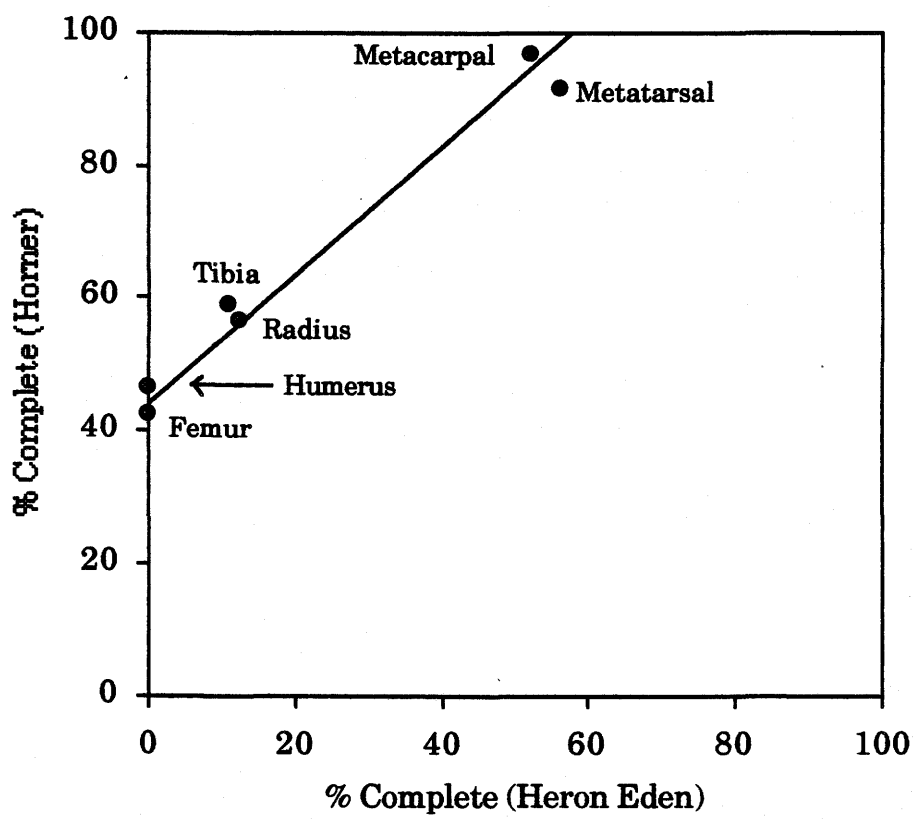


Figure 5.13 The percentage of complete bones from the Heron Eden site compared to the Horner site (modified from Todd and Rapson 1988).

are considered separately, low values are observed. The comparison of the percentage differences of the humerus and tibia are used to assess the nature of destruction (Todd and Rapson 1988:313). Figure 5.12 presents the percentage difference of the humerus and tibia for several Plains kill sites. With additional supporting evidence Todd and Rapson (1988:312) suggest that the curve may reflect increasing carnivore modification.

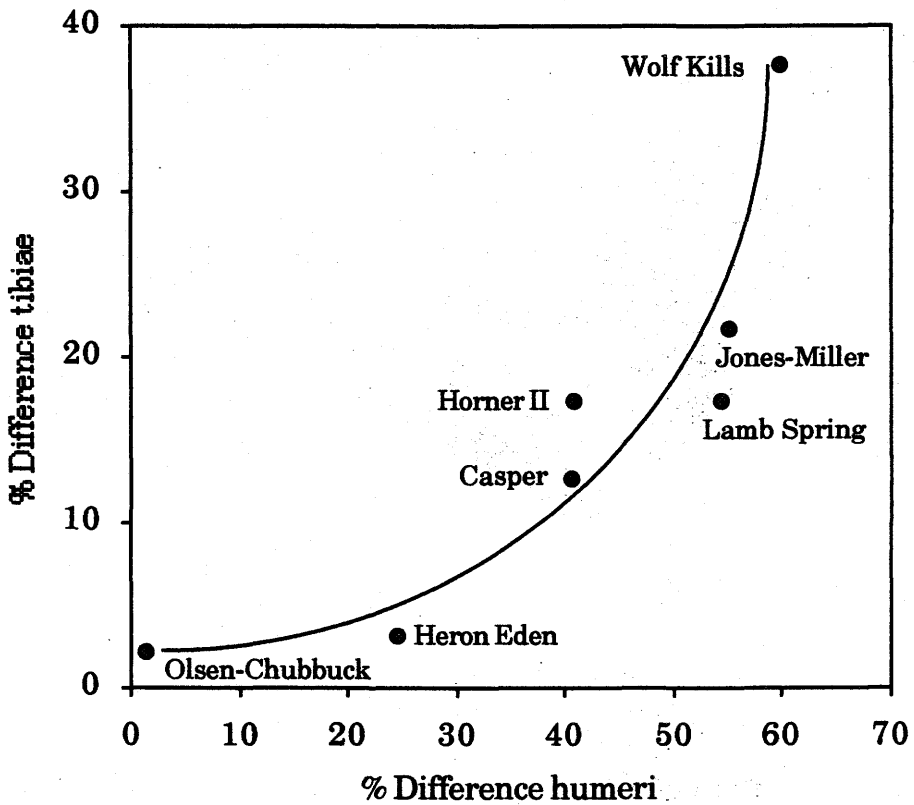


Figure 5.12 Percentage difference from the humeri and tibiae from select sites (curve visually fitted) (Modified from Todd and Rapson 1988:310).

The graph indicates that the wolf kill sample has a greater percentage difference for both elements, unlike the Olsen-Chubbuck site where there are almost equal numbers for the proximal and distal ends of both elements. The data for the Olsen-Chubbuck site (Wheat 1972) "indicates limited

carnivore destruction, probably linked to limited access by carnivores" (Todd and Rapson (1988:312). The low Heron Eden site percentage difference is between the Olsen-Chubbuck site and the Horner II site values. At the Horner site, "although there is clear carnivore modification to some of the bones ... the degree of carnivore modification was minimal" (Todd 1987a:151). In sum, even though the percent complete values are low for the Heron Eden long bones, the percent difference data indicate that carnivore attrition was not a significant factor in element destruction at the site.

Todd and Rapson also note that:

> ... this approach is merely *documenting patterns of differential destruction and not directly indicating processes responsible for the observed differences*. A number of processes, including deliberate fractures for marrow removal and smashing of articular ends for extraction of bone grease by humans, or post-depositional chemical deterioration can also result in patterned destruction of the low density, high grease content components of an assemblage [Todd and Rapson 1988:313; emphasis original].

The Bugas-Holding site, a Late Prehistoric occupation site, exhibits extreme differential destruction of articular ends, attributed to intensive cultural processing, rather than severe carnivore damage (Todd and Rapson 1988:313). Brink and Dawe (1989:86-95) also suggest that the extreme differential destruction of articular ends may illustrate changes in the intensity of bison processing from Paleoindian to Late Prehistoric times. Although the cause of the damage of the Head-Smashed-In faunal materials remains unclear, the extreme destruction present could be the result of intensive processing to extract marrow and bone grease. The Heron Eden site data would then suggest a situation similar to other Paleoindian kill-butchery sites in that there is little intensive cultural processing to extract marrow and bone grease.

5.5 Summary

The Heron Eden site faunal assemblage is in a poor state of preservation. The high degree of weathering and fragmentation have obscured all direct evidence of cultural processing. Consequently, determining the degree to which cultural processes affected the Heron Eden faunal assemblage is severely limited. No definite cut marks were observed on the bone and the majority, if not all, of the bone breakage is due to attritional processes. Additionally, no direct evidence for scavenging was observed; and carnivore activity was not likely a significant factor in element destruction.

Cultivation has had a major impact on the Heron Eden bone bed, affecting both the individual elements and the total faunal assemblage. The differential destruction of elements in the plowzone is considered a direct result of cultivation, both from the mechanical fragmentation of the elements by the cultivator and from deterioration due to exposure. This differential fragmentation alters the general structure of element completeness in the plowzone sample. Cultivation has also altered the paleosol bone specimen frequencies, to an increasing extent westward of the area of maximum specimen density. From the area of maximum density in the contiguous excavation block, proceeding west, the frequency of faunal specimens decreases as the paleosol progressively thins due to cultivation. The paleosol continues beyond the bone bed eastward of the area of maximum faunal specimen density, and provides the only still existing "natural" margin of the site. To the north, south, and west a combination of cultivation and sedimentary deflation has removed the paleosol and associated faunal material.

There is a significant positive correlation between the paleosol element frequencies and bone mineral density when all the skeletal elements are included. The correlations remain positive when the elements are separated into anatomical groupings, but only the hindlimb comparison is significant. The proximal and distal portions of long bones also correlate significantly when they are considered as a group. When individual elements are considered, there are no significant correlations between the bone portions and the associated bone mineral density.

There is a significant negative correlation between element frequency and economic utility when all elements are considered. No significant correlations are observed when the element groups are considered, nor when proximal and distal ends of long bones are compared as a group. As previously noted, bone mineral density has a significant negative correlation with economic utility. Therefore, the relationship between the paleosol element counts and utility is likely the result of density-mediated element destruction.

Overall, it is suggested that density-mediated destruction is the primary determinant of the paleosol skeletal element frequencies at the Heron Eden site. Post-occupational weathering has largely obscured the results of any previous bone modification processes.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Summary

Heron Eden is a Paleoindian bison kill-butchery site located in southwestern Saskatchewan on the northwestern periphery of the Great Sand Hills. Paleoindian projectile points, identified as of the Scottsbluff and Eden types of the Cody complex, are associated with the bone bed. The bison bone has been radiocarbon dated to approximately 9000 years ago. Three radiocarbon dates, 8930 ± 120 (S-3114), 9210 ± 110 (S-3308), and 8920 ± 130 (S-3309) fall into the range of ages assigned to the Cody complex while two dates, 8160 ± 120 (S-3208) and 10,210 ± 100 (S-3118) are outside this range.

The Heron Eden faunal assemblage is composed primarily of bison. Based on element counts, the bison assemblage consists of a minimum of 37 animals. Other animals considered contemporaneous with the bison assemblage include one gray wolf (*Canis lupus*) and one pronghorn (*Antilocapra americana*). Based on the results of the gender analysis, the bison assemblage is dominated by males, which account for 80% to 87% of the measured elements. However, there is an underrepresentation of immature specimens in the sample because these are more susceptible to weathering and are consequently unmeasurable. Support for a higher frequency of immature specimens is the number of individual teeth in the younger age groupings.

The taxonomic position of the Heron Eden site bison is not entirely clear. Univariate comparisons of the gender measurements suggests that the

Heron Eden females are similar to both those identified as possible *B.b. occidentalis* and those tentatively assigned to *B.b. antiquus*. The Heron Eden males are larger than those identified as *B.b. occidentalis* and similar to those identified as *B.b. antiquus*. On the basis of this analysis, the Heron Eden bison assemblage is tentatively identified as *B.b. antiquus*. However, the absence of complete crania or horn cores prevents the confident assignation to a bison subspecies.

The Heron Eden bone bed is composed of two groupings: males and female/ immatures. The living-structure mortality profile supports the presence of a mixed male, female, and immature assemblage. The dental eruption and wear patterns indicate that the kill events occurred within a relatively short time period sometime during December or January. Typically, in the winter season, bull herds (males) are separate from nursery herds (females and immatures). Therefore, the Heron Eden bone bed appears to be the result of two mass kill events, one involving a bull herd and the other a nursery herd.

Cultivation has had an immense impact on the Heron Eden bone bed. The differential fragmentation of bone in the plowzone has reduced element completeness. Therefore, the plowzone aggregate was only utilized in the analysis of the bison herd population structure. Additionally, cultivation has reduced both the horizontal and vertical extent of the bone bed obscuring the structure and composition of the site.

The Heron Eden faunal assemblage is in a poor state of preservation. There is a lack of element articulations and areas of special concentration such as bone piles, butchering areas, and hearths. There is a lack of patterning in the distribution of both the faunal and lithic specimens. The bone bed is characterized by an area of higher concentration around which

there is a general decrease in the amount of faunal material per square meter. The degree of bone fragmentation and surface degradation obscures any direct evidence of cultural modification. No definite cut marks were observed on the bone and the three specimens which exhibit polishing may be attributed to natural processes. Additionally the majority, if not all of the bone fragmentation, is interpreted as being dry-bone breakage and therefore resulted from natural attritional processes.

The primary determinant of the paleosol skeletal element frequencies at the Heron Eden site is density-mediated attrition. A variety of physical and chemical post-occupational attritional processes have largely obscured the results of previous bone modification processes, if any were present. These include post-occupational weathering, rodent gnawing and burrowing, rootlet growth, and the presence of calcium carbonate coatings on the bone. Although it is likely that scavengers had a role is the dispersal and modification of the bison remains after humans abandoned the site, no indication of that kind was noted. There is no direct evidence for carnivore attrition and carnivore activity was likely not a significant factor in element destruction.

The Heron Eden site is located on a small knoll in a cultivated field. The surrounding area is characterized by flat to gently undulating sandflats. Long term cultivation in the area has artificially leveled the surface topography. It is likely that the bone bed itself is resistant to erosion so as to cause the site location to become a small knoll. The nearest prominent landform, a lake strandline, is located approximately one kilometer to the north of the site. Therefore, there are no topographic features in the immediate area of the Heron Eden site to indicate the method of bison procurement that was used. Although only one margin of the bone bed was

excavated, no post molds, which would suggest some type of corral impoundment, were found.

It is also possible that the kills took place nearby and that the animals were butchered and brought to the site for secondary processing. The analysis of the lithic collection (Linnamae and Johnson 1993) suggests that the lithic assemblage represents a special purpose activity, such as bison carcass processing, not a mass kill event. However, both the dispersal and deletion of faunal elements at the Heron Eden site are largely attributed to post-occupation density-mediated attritional processes, not cultural processing decisions. This suggests that the Heron Eden site represents both the kill and the butchering locale.

6.2 Intersite Comparisons

Evidence of cultural utilization from Paleoindian bison bone beds is often limited (Todd 1991:224). Post-occupational density-mediated attritional processes are often the primary factors in the fragmentation, dispersal, and deletion of bison remains at these sites. Additionally, the presence of an obvious geomorphic trap is not always a characteristic at these mass kill-butchery sites (Todd 1987c:232). The prevalent seasonality for most of the Paleoindian bison bone beds is late fall through early winter; although sites with winter, spring, and summer seasonalities are present (Todd 1991:218). Todd (1991:229) also suggests that there is no seasonal variation in the patterns of Paleoindian bison processing.

The Horner site is an Alberta/Cody complex site with mixed short-term occupation and mass bison kill-butchery areas (Frison et al. 1987). No geomorphic feature that could be regarded as a natural trap is present at the site. "Even though there is no evidence to prove it, a structure of some kind

.. seems highly likely" to trap the bison (Frison et al. 1987:369). At the Jones-Miller site, a Hell Gap winter bison kill-butchery site with no evidence of a natural trap, Stanford (1978:95-97) suggests the use of a pound, made of perishable material, or the use of snow drifts as the trap containment. The bone bed at the Horner II locale is interpreted as the primary kill and butchering location which occurred in the late fall or early winter. Although some selective processing of the bison was evident, much of the disarticulation and dispersal of the faunal remains at the site may have been the result of post-occupational processes rather than intentional dismemberment by humans (Frison et al. 1987:366-367).

The Finley site is a Cody complex bison kill-butchery area located on the edge of a sand dune field (Haspel and Frison 1987:475). It is likely that the Finley site was a sand dune trap similar to the Casper site, a Hell Gap late fall to early winter bison kill site (Frison 1974; Reher 1974; Wilson 1974). Severe bone weathering and modifications by looters searching for projectile points at the Finley site have obscured any effects of cultural utilization (Haspel and Frison 1987:489). The seasonality of the Finley site is late fall-early winter (Todd and Hoffman 1987).

An exception to the pattern of late fall-early winter Paleoindian bison bone beds is the Olsen-Chubbuck site. This site is a Cody complex (Bradley and Frison 1987:225) kill-processing area associated with a natural arroyo trap (Wheat 1972:21). It has an assigned seasonality of late summer or early fall (Wilson 1974). Another exception is the Scottsbluff Bison Quarry, a Cody complex site with a late spring-summer seasonality (Todd et al. 1990). The Olsen-Chubbuck site had a high degree of element articulations with both unbutchered and partly butchered animals, and processing bone piles (Wheat 1972:62-70). The limited bone destruction at the site and the nature

of bone preservation may be a function of the narrow arroyo which contained the bone bed (Todd 1987c:257).

The Heron Eden site is a Cody complex bison kill-butchery area located on the northwestern periphery of the Great Sand Hills. No feature that could be regarded as a natural trap is present near the site. This bone bed is interpreted as a primary kill and butchering location which occurred in early winter. The dispersal and composition of the faunal remains at the site is primarily the result of post-occupational processes.

6.3 Conclusions

This thesis presents the archaeology of the Heron Eden site and emphasizes the taphonomic analysis of the faunal assemblage. The research objective was to assess how the procurement strategy exhibited by the Heron Eden bone bed corresponds to the patterns observed at other Paleoindian kill-butchery sites of this general age. It was the goal of this study to evaluate the degree to which bone bed composition and distribution can be attributed to intentional cultural activity. This was completed by reconstructing the bison herd population structure and evaluating the effect of post-occupational processes.

Considering the degree of weathering exhibited by the faunal assemblage, the procurement strategy exhibited by the Heron Eden bone bed generally corresponds to the pattern observed at other Paleoindian kill-butchery sites. The Heron Eden site is the product of two mass kill events which occurred within a relatively short time period sometime in early winter during December or January. There is no surviving geomorphic feature in the immediate area of the site which could have been used to contain the bison. Some type of perishable enclosure or the use of snow drifts

as a winter trap containment might have provided the containment necessary to trap and dispatch the two herds. The presence of two kills, occurring within a relatively short time period within the same bone bed, would likely require some type of containment to trap and kill the animals.

Determination of the effects of cultural activity on the faunal assemblage at the Heron Eden site is severely limited. The faunal assemblage is in a poor state of preservation. The degree of bone fragmentation and surficial bone degradation hinders analyses concerned with the detection of cultural and natural modifications of the surfaces. There are no definite indications of cultural modifications on the bone. The effects of scavenging, like cultural modifications, are obscured by the high degree of weathering. The fragmentation, dispersal, and deletion of the bison bone is primarily the result of post-occupational density-mediated attritional processes. The structure of the bone bed exhibits little evidence of the effects of human activity at the site.

The strategy of bison procurement at the Heron Eden site may never be fully recognized, yet the significance of the site is certain. It is one of only three Cody complex sites to be found with intact deposits in Saskatchewan. It is the only bison kill-butchery site of this age to be investigated in the province. The Heron Eden site also represents the most northern Cody complex site yet found on the Great Plains. Accordingly, the information presented here is the first of its kind in the province and has hopefully contributed to the overall understanding of Paleoindian occupation in Saskatchewan and on the Great Plains.

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APPENDIX A
BISON ELEMENT MNE PORTION COUNTS

Table A.1 Heron Eden site element MNE portion counts*.

Anatomical group Element portion	Plowzone MNE	Paleosol MNE	Total MNE	Total MNE Axial	Total MNE Left	Total MNE Right
Axial						
Cranium						
petrous portion	8	35	43		20	23
external auditory meatus	0	24	24			
occipital condyle	1	14	15			
basioccipital	1	1	2			
other cranial	0	9	9			
Mandible						
coronoid process	2	17	19			
articular condyle	3	19	22			
mandibular foramen	0	11	11			
angle	0	9	9			
lower border	n/c	n/c	n/c			
alveoli	n/c	n/c	n/c			
diastema	2	23	25		16	9
symphysis	0	14	14			
incisor/canines	6	127	133			
premolars	12	97	109			
first molar	4	44	48			
second molar	4	50	54			
third molar	7	65	72		37	35
Hyoid	0	11	11		6	5
Sternum	0	2	2	2		
Rib head	5	141	146		n/c	n/c

continued

Table A.1 Heron Eden site element MNE portion counts*.

Anatomical group Element portion	Plowzone MNE	Paleosol MNE	Total MNE	Total MNE Axial	Total MNE Left	Total MNE Right
Axial (continued)						
Atlas	2	15	17	17		
Axis	1	17	19	19		
Cervical	1	61	62	62		
Thoracic	3	128	131	131		
Lumbar	1	90	91	91		
Sacral	0	28	28	28		
Caudal	2	40	42	42		
Forelimb						
Scapula						
glenoid cavity	3	43	46		18	28
coracoid process	2	16	18			
neck	1	31	32			
spinous process	n/c	n/c	n/c			
acromion	n/c	n/c	n/c			
superior border	n/c	n/c	n/c			
inferior border	n/c	n/c	n/c			
	n/c	n/c	n/c			
Humerus						
lateral tuberosity	0	1	1			
medial tuberosity	0	1	1			
head	1	23	24			
proximal shaft	0	8	8			
deltoid tuberosity	0	7	7			
teres tuberosity	0	9	9			
postero-lateral foramen	1	18	19			
proximal olecranaon fossa	.	7	7			
coronoid fossa	2	37	39			
lateral epicondyle	1	12	13			
medial epicondyle	1	11	12			
lateral condyle	0	30	30			
medial condyle	3	38	41		19	22

continued

Table A.1 Heron Eden site element MNE portion counts*.

Anatomical group Element portion	Plowzone MNE	Paleosol MNE	Total MNE	Total MNE Axial	Total MNE Left	Total MNE Right
Forelimb (continued)						
Radius						
lateral glenoid cavity	5	27	32			
medial glenoid cavity	2	31	33			
proximal- posterior shaft	1	25	26			
radial tuberosity	2	28	30			
Postero-lateral foramen	0	16	16			
mid-posterior shaft	0	21	21			
mid-anterior shaft	0	18	18			
distal-posterior shaft	0	13	13			
distal-anterior shaft	0	16	16			
radial carpal facet	3	29	32			
internal carpal facet	1	39	40		22	18
Ulna						
proximal epiphysis	0	23	23			
olecranon process	1	26	27			
anconeal process	4	38	42		24	18
semilunar notch	0	29	29			
coronoid process	1	18	19			
proximal shaft	0	16	16			
mid-Shaft	1	20	21			
styloid process	1	31	32			
Radial carpal	11	51	62		27	35
Internal carpal	8	50	58		24	34
Ulnar carpal	6	48	54		24	30
Accessory carpal	5	35	40		18	22
Carpal 2+3	11	46	57		28	29
Carpal 4	9	56	65		30	35
5th metacarpal	5	29	34		16	18

continued

Table A.1 Heron Eden site element MNE portion counts*.

Anatomical group Element portion	Plowzone MNE	Paleosol MNE	Total MNE	Total MNE Axial	Total MNE Left	Total MNE Right
Forelimb (continued)						
Metacarpal						
carpal 2+3 facet	2	37	39			
carpal 4 facet	2	38	40			
anterior shaft	0	36	36			
posterior shaft	0	32	32			
anterior foramen	1	43	44		22	22
posterior foramen	1	43	44			
medial condyle	1	35	36			
lateral condyle	1	35	36			
Hindlimb						
Innominate						
Ilium blade	0	9	9			
Ilium Shaft	0	8	8			
Ilio-Isch Border	0	3	3			
Acetab-Ilium	1	41	42		19	23
Acetab-Icsh.	3	33	36			
Acetab-Pubis	1	15	16			
Ishium Shaft	0	17	17			
Ischial Tuber	0	2	2			
Pubis Shaft	1	11	12			
Pubic Symphysis	0	1	1			
Femur						
Head	3	39	42		21	21
Greater Trocanter	0	1	1			
Lesser Trochanter	1	10	11			
Anterior Shaft	0	14	14			
Linea Aspera	0	10	10			
Post-Med foram	0	12	12			
Supracond Fossa	1	19	20			
Prox Trochlea	0	13	13			
Medial Condyle	1	23	24			
Lateral Condyle	0	7	7			

continued

Table A.1 Heron Eden site element MNE portion counts*.

Anatomical group Element portion	Plowzone MNE	Paleosol MNE	Total MNE	Total MNE Axial	Total MNE Left	Total MNE Right
Hindlimb (continued)						
Patella	3	31	34		16	18
Tibia						
Tibial Tuberosity	0	5	5			
Medial Condyle	1	24	25			
Lateral Condyle	0	30	31			
Anterior Crest	0	17	17			
Post-lat Foramen	1	23	24			
Prox-Post Shaft	0	25	25			
Dist-Post Shaft	0	33	33			
Dist-Ant Shaft	0	29	29			
Medial Groove	4	33	37		20	17
Lateral Groove	2	33	35			
Fibular Facet	2	25	27			
Calcneus						
Proximal Epiph.	4	37	41			
Tuber Calcis	3	44	47			
Sustentaculum	3	46	49		22	27
Fibular Facet	3	40	43			
Tarsal C+4 Facet	4	44	48			
Astragalus						
proximal condyles	5	45	50		23	27
distal condyles	5	45	50			
Tarsal C+4						
lateral	10	51	61		33	28
medial	9	47	56			
Tarsal 2+3	6	57	63		36	27
Tarsal 1	2	17	19		9	10
Lateral malleolus	7	42	49		26	23
2nd metatarsal	4	18	22		11	11

continued

Table A.1 Heron Eden site element MNE portion counts*.

Anatomical group Element portion	Plowzone MNE	Paleosol MNE	Total MNE	Total MNE Axial	Total MNE Left	Total MNE Right
Hindlimb (continued)						
Metatarsal						
Tarsal C+4 Facet	1	38	39		17	22
Tarsal 2+3 Facet	3	33	36			
Anterior Shaft	0	38	38			
Posterior Shaft	0	36	36			
Anterior Foramen	1	40	41			
Post Foramen	0	36	36			
Medial Condyle	0	26	26			
Lateral Condyle	1	28	29			
Other Appendicular						
1st phalanx	17	215	232			
2nd palanx	21	197	218			
3rd phalanx	4	175	179			
Sesmoids						
superior-lateral	24	125	149			
superior-medial	25	135	160			
inferior	6	79	85			

* Refer to Morlan (1994b) for complete description and methodology.

APPENDIX B
BISON BONE MEASUREMENTS

Table B.1 Heron Eden site calcaneus data (mm).

Specimen	Wd	Dd	Wp	Dp	Lt	Lc
127	44.0	63.5 c	37.0	42.0	34.5	39.5
399	46.0	58.0 w			33.0	40.5 c
400	48.5 w	65.5	45.0	46.0		
401	41.5 w	63.5	38.5 c	41.5	34.5	38.5
547					33.5	
945	48.0	66.5	41.5		36.0	43.5 e
1056	48.0	61.5 w			38.0	40.5
2158		70.0 r	48.0	49.0 we	40.5 we	44.0
2315	48.0 w	68.0		48.0		
2538		64.0 w				
2828					38.0 w	
3289	47.0	66.0	39.0	45.0	36.0	39.0
4098						43.0
4391	48.5	67.0	43.0	44.0	36.0	41.5
4401				41.5 w		
4609		68.0 w			37.0 we	45.0 w
5197		67.0	43.0	46.0	37.5 w	41.5 w
5208	42.5 w	66.0 w			39.0 we	43.0 r
5454		65.5	46.0	51.0	37.5 we	42.0
5560			40.0	39.5	36.0 we	
5843					38.0 w	
6094		68.0	45.0	46.0	37.5 we	45.0 we
6838		68.0	46.0 w	47.0	37.5 w	43.5 w
6959			46.0	48.0		
7115					34.5 w	43.0 w
7534		70.0c c	45.5 w	47.0 w	35.5 w	
7549	51.5	72.0	41.0 we	45.5	39.0	45.5
7552					36.5	
7821	46.5 wc	69.0	43.0 we	47.5 w	40.0 w	
8166	49.0	66.5 wc	47.0	51.0	36.0	
8290			45.5	48.0	34.5 w	
8329	55.0	67.0 c	44.0 w	52.5	41.5	48.0 we
8932					34.0	
9128		70.5 w			43.5 w	

Abbreviations: Wd = distal width, Dd = distal depth, Wp = proximal width, Dp = proximal depth, Lt = talar facet length, Lc = C+4 facet length, w = weathered, c = calcium carbonate, r = refitted, and e = estimate taken.

Table B.2 Heron Eden site radial carpal data (mm).

Specimen	W	L	D
21	35.5 w	36.5 w	58.5 w
57	37.5 wc	40.5	59.0
202	33.2 w	36.2	50.5
393	31.0 w	34.5	51.0
527		33.0	
576	35.0	35.0	57.0
844	37.0 w	39.5	57.0
876	32.5 c	33.0	54.2
877	31.5 w	35.5 w	57.0
878	32.7 e	33.2	57.5 c
879	36.0 w	41.0	59.0
1618		35.0 w	51.0 w
2357	34.5	37.0	56.5
2425		39.0	
2521	25.5 w	29.0	43.0 w
2708	35.0 w	36.7 w	59.7
3272	32.8	35.8	56.5
3397	37.0	37.0	58.5
3531		36.0 w	57.5 w
3731	32.0 w	34.0 w	54.0 c
3953	26.5 w	31.0	
4015	30.0 w	31.0 w	49.0 c
4239	32.3	35.0	54.0 c
4361		39.0 w	
4698	35.0	39.0 w	59.0 c
4777	35.0	38.0	58.0
4884	33.0	36.0	53.5
4962		35.5 w	55.5 c
5191	36.0 w	40.0	57.5

continued

Table B.2 (continued) Heron Eden site radial carpal data (mm).

Specimen	W	L	D
5563	34.5 w	36.0 w	
5593	36.0	37.0	58.0
5955	33.5	37.0	55.5
5994		38.0	55.0 w
6217		40.0 w	
6433		37.2 w	56.7 w
6441	31.5 w	35.2 w	54.2 w
6666		37.5 c	58.5
6921	35.0	36.0	59.5 c
6971	36.5	38.0	56.0
7232		37.0 w	
7903		36.0 w	55.5 wc
8014	32.5 w	34.0 w	53.0
8246	40.0 w	40.0	64.0 c
8277		36.0 w	
8307	33.0	37.0	57.0
9051	33.5 w	36.0	56.0
9196	34.0 w	36.5	
9367	34.0	35.8	56.2 w
9531			48.0 w

Abbreviations: W = width, L = length, D = depth, w = weathered surface, c = calcium carbonate coating, and e = estimate taken.

Table B.3 Heron Eden site internal carpal data (mm).

Specimen	L	D	W
204	33.0		40.5 wc
205	31.0	49.0 wc	35.0
293	29.0 c	43.5 wc	30.0
392	28.0	45.5	32.0 w
394	37.0	57.5 w	42.0
520	31.0 w	48.5 w	36.0
575	33.5	54.5	38.5
719		44.0 w	28.5 wc
1075	29.2 w	43.7 w	30.5 w
1539			34.0
1831		45.5	33.5
1870	35.5	52.0	39.5 w
2001	35.5 w		39.0
2190	31.0 c	51.0 wc	35.0 w
2418	35.0 c	57.0 w	40.0
2421	31.0 w		38.0 w
3008	30.5	52.5	35.5
3035	32.8	55.8	36.5
3276	33.0 w	52.5 e	37.0
3317			32.0 w
3331			32.0 w
3658	32.5	55.0	37.5
3957	32.5	51.5	33.0
4248		52.0 r	37.0
4558	33.0	53.0 e	37.5
4785	34.0	59.0	41.5
4963	33.2	56.2	39.0
5038			34.0 e
5149			37.0 w

continued

Table B.3 (continued) Heron Eden site internal carpal data (mm).

Specimen	L	D	W
5531	34.5 w	58.0	40.5
5586	35.0	56.0	41.0
5995	34.0	53.5	38.0
6223	34.0 w	57.0	40.5
6432	33.0	58.0 wc	39.0
6470	35.5	55.0 w	40.0
6636	33.5 w	53.0 e	37.0
6656			32.0 w
6703	32.8	56.2	39.0
6815	32.0		39.0
6963	35.5	54.0 w	39.0
7241	32.5 w	56.5	39.0
7902	34.0	54.5 wc	40.0
8013	32.5 w	52.5	38.0
8368	35.0	53.0 w	40.0
8510	32.5	53.0 w	37.0 w
8520	32.5	55.5	37.0 w
8785	36.5	56.0 w	41.0 w
8991	26.0	42.0 w	31.0 w
9127	33.0	56.0	38.0
9733	32.0	49.0	31.5
10064	33.5 we	56.0 w	36.5 w

Abbreviations: L = length, D = depth, W = width, w = weathered surface, c = calcium carbonate, r = refitted, and e = estimate taken.

Table B.4 Heron Eden site ulnar carpal data (mm).

Specimen	La	D	Lp
203	37.5	45.0	43.0
448	35.0 w	41.0 wc	39.0 w
720	37.5	44.5 c	46.0
880	34.0	41.0 w	47.5
937	38.0 w	48.0	47.0 w
1148	32.0	37.0 w	37.0
1149	32.0 wc	37.5 w	
1747	38.2	44.2	43.8
2280	36.5 w	44.0 w	
2561		46.0	46.5
2789	37.8	45.8 w	45.8 w
3083		41.0	43.0
3233	32.0 w		
3399	35.0	43.0	
3643	37.8	45.2	45.0 w
3952	34.0 w	40.5 c	40.0 w
4014	38.0 w	46.0	
4242	38.2 w	45.2 c	
4385	39.0 w		
4888	37.5	43.0 w	45.5 w
5044	37.5 w	47.5	47.5 w
5221	39.0	46.0 w	45.0 w
6319	34.0 w		
6328	38.5 we	45.5 w	44.0 we
6520	35.8 w	43.2 w	44.0
6704	37.5	46.5 w	45.5 w
6800	38.2	46.2	46.0
6969	40.0	43.5	46.0 w
7127	40.0 w	47.0 w	49.0 w

continued

Table B.4 (continued) Heron Eden site ulnar carpal data (mm).

Specimen	La	D	Lp
7234	36.0 w	45.0 w	44.5
7240	37.2 w	43.8	46.0
7361	32.0 c	40.0 w	37.0 w
7697	32.0 e	38.5 w	
7861	35.0 w	44.0 w	42.0 w
7888	36.0 w	46.0	
7906	35.8 w	43.8 w	44.0
8141	36.0 e	43.0 w	
8428	41.0	46.0	46.2 w
8505	38.0 w	43.8	44.2
8543	38.0	45.0	46.0
8724	41.0	45.0	47.5
8930		45.5 w	
9047	36.0 w	44.0 w	
9111	37.0 w	44.0 w	

Abbreviations: La = anterior length, D = depth, Lp = posterior length, w = weathered surface, c = calcium carbonate coating, and e = estimate taken.

Table B.5 Heron Eden site carpal 2+3 data (mm).

Specimen	D	W	Specimen	D	W
22	38.5	41.0	3840	43.5 w	46.5 we
96	45.5 w		4167	46.5	50.5 c
206	43.0 wce		4237	45.0 w	47.0 w
471	51.0	54.5	4779	47.5 w	
728	46.0	50.0	4886	47.0 w	48.0 w
882	45.0 wce	48.5 wce	5035	45.2	48.2
883	48.0	50.5 we	5256	48.2 w	52.2
938	44.5 w	49.0	5539	47.0	51.0
939	46.0	47.0 w	5780	48.5 w	48.0
940	45.0 w	50.5	6221	45.5 w	49.0
1151	39.0	40.0	6817	47.2	51.2
1450	45.0 we		6970	47.2	48.2
1756	46.0 we	53.0	7864	44.0 wc	49.0
2000	42.0 we		7890	45.0 w	46.5 wce
2025	37.0 we	41.0 w	7904	42.0 w	47.0 we
2294	43.0 w	48.0 w	8138	42.0 we	44.0 w
2658	40.5 w	45.5 we	8729	46.0	49.0
2711	48.0	52.0 w	8943	46.2	49.2
2976	46.5	50.0 w	8945	49.0	49.0 c
3287	45.0	48.0 w	9315	46.0	51.0
3574	46.0	48.5 w	9421	48.0 w	51.5 w
3701	46.5 we				

Abbreviations: D = depth, W = width, w = weathered surface, c = calcium carbonate coating, and e = estimate taken.

Table B.6 Heron Eden site carpal 4 data (mm).

Specimen	W	D	L
472	39.5	42.5	30.0
499	37.0	41.5	31.0
721	38.0	45.0	31.5 w
722	32.0 wc		
884	40.0	41.7	32.2 wc
941	36.0 wc	42.0	30.0
942	33.5	39.0	29.0
943	37.0 w	42.5	31.0 w
1076	30.5	34.0	26.5
1152	29.5	35.0	26.0 w
1408	34.5 w	39.0	30.0 w
1736	39.5	45.0	33.0
1961			29.0 w
2102	36.0	41.0 w	
2121	35.0	42.0	32.5
2415	39.0 w	46.0 w	33.5
2609	39.0 w	44.0 w	
3013	33.5	37.0 w	29.0
3050	35.0	38.0	
3400	39.0	45.0	30.5 w
3771	35.5	42.8	32.3
3848	36.5	42.0	32.0
3949	41.0	43.0	33.0 w
3950	34.5	40.0	29.0
4312	39.0 w	39.0	31.0
4871	37.0	42.0	30.5
4887	36.0 w	40.5	31.5 wc
5145	40.0	42.5	31.5 w

continued

Table B.6 (continued) Heron Eden site carpal 4 data (mm).

Specimen	W	D	L
5217		42.0	
5554	39.0	43.2	32.7 w
5584	39.0	42.0	33.0
5729	37.5	43.0	34.0
6219	41.0 w	39.0 w	32.5 w
6469	37.0	39.0	30.5
6697	39.2	43.2	
6967	38.5	43.0	32.5 w
7085	36.0		30.5 w
7128	38.0 w	41.7 w	31.2 w
7249	39.0	41.0	31.0
7405			33.0 w
7577			27.5 w
8016	38.5 w	39.5	31.0
8341	41.0	44.0	34.0
8721	39.2	44.2	33.0
9226	36.0	41.5	32.0
9697		38.5 w	30.0 w
9858	38.8 w	42.8 w	31.3 w

Abbreviations: W = width, D = depth, L = length, w = weathered surface, and c = calcium carbonate coating.

Table B.7 Heron Eden site astragalus data (mm).

Specimen	Ll	Lm	Wd	Wp	Dm	Dl
214	86.0 we	77.5 we	58.5 we	58.5		48.0 w
480	75.0	70.0	49.0 w	51.0 c		42.0
579	75.0	74.0	52.0 w	51.0 w	44.5	42.0
727	75.5 w	72.5				
784	82.5	78.5	56.0	58.0	48.0	46.0
1465	79.0 w	74.0 w	53.5 w	54.0 w		43.5 w
1749	77.0 w	71.5 w	45.5 we			44.5 w
1811	81.0 we	78.0	53.0	56.0		45.5 w
3286	79.0	76.0	49.5 w	53.5		44.5
3545	84.0	79.0	58.5 w	59.0 w		46.5 w
3656		74.5 we				
4069		80.0		58.0 w	46.5 w	
4073	84.0 we	81.0	59.0	59.0		47.0 c
4102		76.0 we				
4208	82.0 w	80.0	55.0 w	55.0 w		47.0 w
5359	80.5	79.0 w	54.0 w	58.5 w	43.5 we	47.0
5424	81.0	78.0	57.0	56.5	47.5	46.0
5435	84.5 e	80.5 wc	61.5 c	60.0 w		49.0 w
5547	75.5 w	70.0	51.0	51.5	41.0 w	43.0 w
5550	81.0	78.0	55.5 w	56.0 w	46.0 w	45.5
5835	84.5	79.5	57.5	61.0	47.5	46.0
5951	85.0	78.0	57.5	61.0	47.0	46.0
7327	83.0 w	78.0	55.5 w	58.5		47.0
7537	82.5	78.0	54.0	58.0	44.0 w	45.0
7553	82.0 we	78.5	53.5 w		44.0 w	46.0 w
7588		73.5 w	54.5 w	56.5 w		46.0 w
7667	80.5	78.0	53.5	56.0	47.0	46.0
7819	81.0 w	78.0	59.0	58.0 c	47.0 w	47.5
7848	83.5 c	80.0	60.5 w	57.0	47.0	47.5

continued

Table B.7 (continued) Heron Eden site astragalus data (mm).

Specimen	Ll	Lm	Wd	Wp	Dm	Dl
7892	82.0	77.0	54.5	55.0	44.5	46.5
7979	81.0	76.5	56.5	56.0	45.5 w	45.5
8071	87.0	83.0 w	60.0	63.5		49.0 w
8083	87.5	82.0 w	61.0 w	62.0	49.0 w	50.0
8311		70.5 w	50.5			
8418	83.0	79.0	55.0 w	59.5	45.5 w	46.0
8508	79.5 c	77.0	56.0	58.0	44.5	44.5
8525		76.5	56.5 r			
9054	84.5	80.0	56.5	61.0	46.5	47.5 c
9126	90.0	81.0	63.0	66.0	49.0	51.0 w
9202	87.0 we	81.5	59.0		48.5	
9534	81.0 w	76.5 w	54.0	58.5		44.5

Abbreviations: Ll = lateral length, Lm = medial length, Wd = distal width, Wp = proximal width, Dm = medial depth, Dl = lateral depth, w = weathered surface, c = calcium carbonate coating, and e = estimate taken.

Table B.8 Heron Eden site Tarsal C+4 data (mm).

Specimen	W	D	Specimen	W	D
126	62.0	61.5 c	5319	74.5	73.0
789	70.0	69.0	5356	72.0 w	64.5
944	71.5	66.0	5370	74.0	72.0
1011	72.0 w	68.0	5431	71.5	67.5
1158	75.0	69.0	5552	59.0	60.0
1298	64.5	61.5	5918	71.0	67.0
1322	61.0	62.0	6893	70.0	68.0
1741	73.5	69.0	6912	72.5	70.0
1767	57.5	54.0 w	7035	71.5	66.0
2036	74.0	68.0	7052	67.0	64.0
2779	72.5 w	67.0 w	7408	72.0	67.0
2879	63.0 w	69.0 w	7535	70.0	67.0
3098	70.5	67.5	7554	62.5 wc	58.0 we
3111	72.0	65.0	7846	68.0	65.5
3277	70.0 w	68.0	7866	68.5	65.0
3281	60.0	61.0	7998	66.0 wc	68.0
4076	67.0 re	66.0 r	8301	70.0	69.0
4382	71.5 w	70.0	9159	73.5	70.0
4479	65.0	65.0	9277	73.0	70.0
5209	66.0 w	65.0	9655	71.5	66.0
5262	67.0 w	64.0			

Abbreviations: W = width, D = depth, w = weathered surface, c = calcium carbonate coating, r = refitted, and e = estimate taken.

Table B.9 Heron Eden site Tarsal 2+3 data (mm).

Specimen	W	D	Specimen	W	D
208	28.5 c	42.0	5917	28.0	45.0
507	30.0	44.0	6825	30.0	45.5
549	25.0	44.0	6909	30.5	48.5
697	31.0 w	50.5 w	7190		43.0 w
726	26.0 w	40.5	7453	29.0	45.5
770	31.0 w	45.0 w	7533	27.5	46.0
1155	30.5	44.0	7680	29.0	45.5
1156	29.5 w	42.0	7847	28.0	46.0
1157	30.0	45.0	7982	30.0	47.0
1321	27.0	41.0	7996	28.5	45.0
1734	24.0	39.0	8090	31.0	44.0
1742	29.5	47.0	8112	30.0 w	46.0
2329		43.5	8291	30.0 w	46.5
2774	27.0 wc		8308	31.0	45.0 w
3097	29.5	47.0	8334	33.5	48.5
4075	29.0	42.5	8489	28.0	44.0
4095		46.0 wc	8994	26.5	38.5 w
4369	30.5	43.5	9053	31.0 w	45.5
4524		39.0	9135	32.0	47.5
5206	29.0	46.0	9276	28.5	48.0
5372	30.5	46.0	9559	29.0	44.0
5610	25.0	39.5	9787	28.5	43.5
5628	28.0 w	48.0			

Abbreviations: W = width, D = depth, w = weathered surface, and c = calcium carbonate coating.

Table B.10 Heron Eden site lateral malleolus data (mm).

Specimen	L	D	Specimen	L	D
211	30.5 w	44.5 w	5210		42.5
212	29.5 w	43.0 c	5371	33.5 w	47.5
331	29.0	45.5	5457	33.0	47.0
403	31.5 wc	43.5 c	5949		44.0
636	29.0 w	40.0	6466	31.0	43.0
637	26.5	37.0	6854		46.5
783		42.0 w	6972		44.0
1033	31.0	42.5	7328		44.0
1078	28.5	37.5	7521		43.0
1159	27.5	38.5	7532	31.0	43.0
1509	29.0 w	43.0 c	7669	28.5 w	44.0
1704	26.5 w	40.0	7867	32.0	45.5
1743	31.0	44.0	7869	33.0	43.5
2134	31.0	40.0	7999		42.0
2726	32.5 w	45.0	8078	33.5 w	46.5
3280	26.5	39.0	8422	29.5	43.0
3398		44.0	8500	31.5	45.0
4360	28.5 w	41.0	9063		47.0
4410		45.5	9533		42.5
4416	35.0	47.0			

Abbreviations: L = length, D = depth, w = weathered surface, and c = calcium carbonate coating.

Table B.11 Metapodial measurement designation codes* (taken from Bedord 1974).

M1	maximum length
M2	width of proximal end
M3	width at center of shaft
M4	width of distal end
M5	depth at center of shaft
M6	depth of proximal end, metacarpal
M7	depth of proximal end, metatarsal
M8	depth of distal end
M9	minimum depth of shaft
M10	minimum width of shaft
M11	rotational length, medial side
M12	distal foramen to prox. articular surface, anterior
M13	distal foramen to prox. articular surface, posterior

*Refer to Bedord 1974 for complete descriptions and methodology.

Table B.12 Heron Eden site metacarpal data (mm).

Specimen		M1	M2	M3	M4	M5	M7	M8	M9	M10	M11	M12	M13
62	Fused	192.0	65.5	37.0		24.5	38.0	35.0	24.0	36.5	164.5	142.5	
217	Fused	223.5		52.5		32.5			29.0	52.5	191.0	165.0	140.5
885	Fused	217.0	77.0	50.0	81.0	34.0	47.0	42.0	30.5	50.0	185.5	162.0	155.0
886	Fused	222.0	85.0	54.0	89.5	32.0	48.0	44.5	30.5	54.0	187.0	166.0	157.0
946	Fused	223.0	85.5	53.0	89.0	32.0	47.0	42.5	30.0	53.0	188.0	168.5	160.0
1050	Fused	204.0	68.0	35.0	68.5	27.0	41.5		25.5	35.0	176.5	153.0	146.5
1057	Fused	203.0	66.0	35.0		27.0	39.5		25.0	35.0		153.5	157.5
3165	Fused	216.5	77.0	48.0	80.0	32.5	45.0	38.0	29.5	48.0	186.0	163.0	154.0
3559	Fused				85.0			40.0	32.0				
4241	Fused	208.5	79.5	48.0	80.5	30.5	46.5	40.0	27.5	48.0	182.0	155.0	152.0
4885	Fused	222.0	82.0	51.0		32.5	50.5		29.0	51.5		166.0	157.0
5718	Fused	221.0	64.0	37.0	65.0	22.0	39.0	37.0	26.5	36.0	194.0	170.5	165.5
6714	Fused	223.0	79.0	55.0			47.0	43.5	30.0	54.5		164.5	144.0
6789	Fused				82.0			42.0					161.0
7845	Fused	208.0	78.5	52.0	80.5	31.5	46.5		28.0	51.5	180.0	157.0	152.0
7885	Fused	209.5	80.0	52.0	83.0	32.0	46.5	38.0	29.0	52.0	179.5	158.5	151.0
8726	Fused	221.0	85.0	51.0	82.0	33.5		43.0	31.5	51.0	186.0	165.5	159.0
8881	Fused	210.0	83.5	50.0	84.0	32.5	49.0	42.5	29.0	49.0	177.0	157.0	150.0
8929	Fused	218.0		51.0	83.5	32.5		42.0	30.5	51.0	182.0	164.0	
469	Indt.		80.0				50.5						
3435	Unfus.								28.0	42.0		157.5	154.4
	Mature specimens only												
	N	17	15	17	14	16	14	14	18	17	14	17	16
	Min.	192	64	35	65	22	38	35	24	35	164.5	142.5	140.5
	Max	223.5	85.5	54	89.5	34	50.5	44.5	32	54.5	194	170.5	165.5
	Mean	214.2	77.0	47.7	81.0	30.5	45.1	40.7	28.7	47.6	182.8	160.7	153.9
	s.d.	9.1	7.5	7.0	6.7	3.5	3.9	2.8	2.2	7.1	7.3	7.0	6.6

Table B.13 Heron Eden site metatarsal data (mm).

Specimen		M1	M2	M3	M4	M5	M6	M8	M9	M10	M11	M12	M13
133	Fused	266.0	54.0	34.0	64.5	32.5	52.0	37.0	28.0	33.5	225.5	194.0	196.0
666	Fused		56.0	34.0	63.0	33.5		38.0	32.0	33.0	216.0	190.0	195.0
2550	Fused	271.0	60.5	43.0	72.5		56.5	41.0		41.0	231.0	197.5	200.0
3775	Fused	268.0	63.5	38.0	73.0	38.5	58.5	40.5	31.0	38.0	225.0	202.0	202.0
4408	Fused	271.0	65.0	44.0	73.5	40.0	58.5	44.5	35.0	43.5	229.0	199.0	199.5
5839	Fused	260.0	61.0	42.5	73.0	36.0	56.0	41.5	31.5	41.0	224.5	196.0	197.5
6907	Fused	264.5	61.0	39.5	74.0	39.5	58.0	40.5	32.0	39.0	220.0	192.0	196.5
6908	Fused	283.0	61.0	41.5	77.0	36.5	59.5	43.5	33.5	40.0	239.5	207.5	209.0
7672	Fused	259.5	64.0	41.5	76.0	37.5	58.0	41.0	32.0	40.0	219.0	188.0	191.0
7862	Fused	261.0	59.0	39.0	70.0	40.0	56.5	41.0	33.0	38.5	223.0	198.0	201.0
7913	Fused	277.5	61.5	40.5	73.0	36.5	59.0	43.0	33.0	40.0	234.0	206.0	206.0
8609	Fused	278.0	61.0	39.0	72.5	38.0	58.0	40.5	34.0	38.0	235.0	205.5	206.0
9630	Fused	277.5	61.5		73.0		58.0	43.5	32.0		233.0	207.5	208.0
2841	Unfus.		54.0	32.5		32.5	52.5		30.0	32.5		195.5	197.5
3919	Unfus.		52.5	32.5		33.0	52.0		30.0	32.5		196.0	197.0
5263	Unfus.		59.0	37.0		35.0			32.5	36.0		198.0	206.0
7539	Indt.		60.0				55.0		33.5	41.0			
8003	Indt.		63.5	41.0		37.0	60.0		32.5	40.0		206.0	209.0
	Mature specimens only												
	N	12	13	12	13	11	12	13	12	12	13	13	13
	MIN	259.5	54	34	64.5	32.5	52	37	28	33	216	188	191
	MAX	283	65	44	77	40	59.5	44.5	35	43.5	239.5	207.5	209
	MEAN	269.8	60.7	39.7	71.9	37.1	57.4	41.2	32.3	38.8	227.3	198.7	200.6
	S.D.	7.9	3.0	3.2	4.0	2.5	2.0	2.1	1.8	3.0	7.0	6.7	5.5

Table B.14 Long bone measurement designation codes*
(taken from Todd 1987b).

Humerus	
HM7	breadth of distal articular surface
HM14	least depth of distal end
Radius	
RD2	greatest length
RD3	greatest breadth of proximal end
RD4	greastest breadth of proximal articular surface
RD5	least breadth of diaphysis
RD6	least depth of diaphysis
RD7	greatest breadth of distal end
RD8	greatest breadth of distal articular surface
RD9	greatest depth of proximal end
RD10	greasest depth of proximal end, lateral margin
RD11	greatest depth of distal end
RD12	greatest breadth of radial carpal articular surface
Ulna	
UL2	greatest height of "cavitas sigmoides major"
UL3	greatest length of olecranon
UL4	greatest breadth of olecranon tuberosity
UL5	greatest breadth of coronoid process
UL7	least depth of olecranon
UL8	least depth at anconeal process
UL9	depth of "cavitas sigmoidea major"
Tibia	
TA6	least breadth of diaphysis
TA7	greatest breadth of distal end
TA9	least depth of diaphysis
TA10	greatest depth of distal end
TA14	breadth of distal articular surface

*Refer to Todd 1987b for complete descriptions and methodology.

Table B.15 Heron Eden site humerus data (mm).

Specimen	Gender	P. fusion	D. fusion	HM7	HM14
3719	male	indt.	fused	103.0	49.0
4228	male	indt.	fused	98.5	48.5
4414	F?	indt.	fused	-	44.0
4865	male	indt.	fused	106.0	54.5
6245	M?	indt.	fused	-	47.5
8511	male	indt.	fused	101.5	46.5
8539	M?	indt.	fused	-	48.5

Abbreviations: P. fusion = proximal maturity, D. fusion = distal maturity, M? = probable male, F? = probable female, ? = indeterminate gender in this analysis, and indt. = indeterminate.

Table B.16 Heron Eden site radius data (mm).

Specimen	Gender	P. fusion	D. fusion	RD2	RD3	RD4	RD5	RD6	RD7	RD8	RD9	RD10	RD11	RD12
102	?	fused	indt.	-	-	-	-	-	-	-	-	38.0	-	-
896	male	fused	fused	368.0	115.0	108.0	61.0	38.0	101.0	97.0	60.0	37.0	66.0	38.0
947	male	fused	fused	-	-	-	60.0	37.0	104.0	100.0	-	-	70.0	40.0
1106	female	indt.	fused	-	-	-	46.0	29.0	80.0	75.0	-	-	55.0	32.0
1731	M?	indt.	fused	-	-	-	-	-	103.0	97.0	-	-	-	39.0
3166	?	fused	indt.	-	103.0	-	-	-	-	-	54.0	-	-	-
3566	?	fused	fused	-	109.0	99.0	-	-	-	-	-	-	-	-
4238	?	fused	fused	-	104.0	95.0	-	-	-	-	54.0	37.0	-	-
5194	?	fused	indt.	-	-	-	-	-	-	-	-	36.0	-	-
6127	M?	indt.	epiphysis	-	-	-	-	-	-	95.0	-	-	67.0	37.0
7096	F?	indt.	fused	-	-	-	-	-	83.0	81.0	-	-	-	31.0
7332	?	fused	indt.	-	-	-	-	-	-	-	-	24.0	-	-
8241	?	fused	indt.	-	-	-	-	-	-	-	-	38.0	-	-
8946	?	fused	indt.	-	110.0	103.0	-	-	-	-	56.0	40.0	-	-
8997	?	fused	indt.	-	-	-	-	-	-	-	-	24.0	-	-
9124	?	fused	fused	-	103.0	94.0	-	-	-	-	-	-	-	40.0
9658	?	fused	indt.	-	93.0	-	-	-	-	-	-	-	-	-

Abbreviations: P. fusion = proximal maturity, D. fusion = distal maturity, M? = probable male, F? = probable female, ? = indeterminate gender in this analysis, and indt. = indeterminate.

Table B.17 Heron Eden site ulna data (mm).

Specimen	Gender	P. fusion	UL2	UL3	UL4	UL5	UL7	UL8	UL9
60	?	indt.	44.5	-	-	-	-	76.5	10.5
389	female	fused	-	119.0	29.0	-	58.5	81.0	-
740	male	fused	-	152.0	37.0	-	75.0	100.5	-
890	?	indt.	55.0	-	-	-	-	105.0	13.0
891	?	indt.	47.0	-	-	-	-	-	11.0
1862	male	fused	-	154.0	40.0	-	75.5	101.0	-
3444	?	indt.	-	-	-	53.0	-	-	-
4211	?	indt.	-	-	-	55.5	-	94.5	-
4232	?	indt.	51.5	-	-	54.5	-	92.5	10.0
4880	?	indt.	49.5	-	-	-	-	93.0	11.5
7975	?	fused	48.5	-	-	49.0	-	-	11.5

Abbreviations: P. fusion = proximal maturity, ? = indeterminate gender in this analysis, and indt. = indeterminate.

Table B.18 Heron Eden site tibia data (mm).

Specimen	Gender	P. fusion	D. fusion	TA6	TA7	TA9	TA10	TA14
957	male	indt.	fused	53.5	79.5	40.0	58.0	58.0
958	male	fused	fused	-	79.5	-	58.0	59.0
1055	F?	indt.	fused	-	70.5	-	-	-
3235	female	indt.	fused	-	74.0	-	56.0	51.0
4384	male	indt.	fused	-	83.0	-	61.5	61.0
4555	male	indt.	fused	-	78.0	-	57.0	58.5
5017	male	fused	fused	52.0	77.0	41.0	58.0	54.5
5025	male	indt.	fused	-	83.5	-	60.0	59.0
6849	male	indt.	fused	-	78.0	-	54.0	55.0
7039	male	indt.	fused	-	81.0	-	54.0	59.0
7531	male	indt.	fused	55.5	80.0	41.0	55.5	55.5
7818	MF?	indt.	fused	-	-	-	56.5	-
8925	female	indt.	fused	-	71.5	-	51.0	54.0

Abbreviations: P. fusion = proximal maturity, D. fusion = distal maturity, F? = probable female, MF? = indeterminate male or female, and indt. = indeterminate.

APPENDIX C
MANDIBULAR MOLAR MEASUREMENTS

Table C.1 Heron Eden site first molar data (mm).

Age group	Specimen	Side		Metaconid Height	Exostylid Occlusal ¤	Exostylid Enamel Δ
2	5	R		48.8	8.6	
	45	L		48.5	8.1	
	1243	L		44.4	-	
	2420	L	*	48.5	8.6	
	6229	R	*	47.8	5.7	
	6322	L		44.9	7.8	
	6691	R	†	52.5	-	
	6888	L		47.4	4.8	
	8595	R		45.9	4.2	
	8612	L	*	46.7	4.0	
3	270	R		43.0	5.4	
	1456	L		40.5	1.2	
	4327	L		42.3	1.5	
	5856	R		-	2.3	
	6554	R	*	41.0	-	
	7822	L	*	42.5	5.7	
	8596	R		41.3	0.0	
	9316	L	*	40.0	1.3	
4	2192	R		35.8		*30.8
	2239	L		35.7		-
	6400	L	*	34.7		30.2

continued

Table C.1 (continued) Heron Eden site first molar data (mm).

Age group	Specimen	Side		Metaconid Height	Exostylid Occlusal ¤	Exostylid Enamel Δ
5	3267	L		30.9		26.4
	4636	L	*	30.6		25.7
	8738	R	*	28.5		27.1
	9147	L		29.4		25.6
	9651	R	†	34.0		-
6	2830	L	*	25.3		21.1
	3106	R	*	23.5		19.5
	4679	L		23.5		17.8
	7856	L	*	27.3		?
	1315	L	*	21.4		16.8
	4969	R		18.7		12.6
7	7295	R		22.2		
8	1733	R	*ı	-		10.9
	8645	R	ı	12.4		14.0
>8	1118	R	‡	7.1		7.7
	3306	L	*‡	9.0		11.6
	5715	R	*‡	7.5		8.0
	7403	R	‡	9.6		9.1

¤ = exostylid measured from occlusal surface
Δ = exosylid in wear, measured from lowest point of enamel
† = measure from ectoconid cusp
* = estimate
ı = prefossette present
>8 = all age goups older than group 8
‡ = prefossette absent

Table C.2 Heron Eden site second molar data (mm).

Age group	Specimen	Side	Wear ◊		Metaconid Height	Exostylid Occlusal ¤	Exostylid Enamel Δ
1	5823	L	erupting	*	58.2		
2	45	L	I,II		66.1		
	269	R	I-IV	*	66.2		
	6006	L		*†	-		
	6227	R	I,II,III		67.1		
	6888	L	I,II		67.8		
	6978	L	I-IV		64.6		
	8597	R	I,II,IV	*	67.0		
	8610	L	I,II,IV	*	68.0		
3	599	R		*	-	12.0	
	2133	L		*	-	15.8	
	2648	R			58.0	11.9	
	3031	L		*	61.8	18.8	
	5983	L		*	-	15.2	
	8528	L		*	59.0	12.4	
	8596	R			58.1	11.6	
4	46	R			55.4	7.4	
	3569	R		*	52.5	6.3	
	3573	R			53.0		45.9
	6402	L			52.7	7.5	
5	3062	R		*	50.9	4.1	
	8716	R			50.7		47.4
	8906	L		*	49.9		42.4
	9148	L		*	49.2		44.5
	9627	R			51.8	6.4	

continued

Table C.2 (continued) Heron Eden site second molar data (mm).

Age group	Specimen	Side	Wear ◊		Metaconid Height	Exostylid Occlusal ¤	Exostylid Enamel Δ
6	1829	R		*	47.8		
	2578	L			44.6		38.3
	3270	L		*	45.8		42.9
	4829	R		*	46.7		41.5
7	81	R		*	41.3		39.5
	1589	R		*	36.0		-
	3105	L			41.9		38.3
	3107	R		*	41.9		39.0
	4862	R			35.8		30.3
	6799	L		*	39.5		38.1
	9218	L			39.0		32.0
	9298	R		*	37.7		31.9
8	1816	R			29.2		25.0
	4405	L		*	29.0		24.4
	8519	R			30.9		26.5
	8645	L			31.2		27.4
>8	5715	R		*	25.5		20.2
	6798	L		*	22.0		22.0
	7370	L			17.1		12.8
	7403	R			20.1		15.3

◊ = descriptions of tooth cusps coming into wear
¤ = exostylid measured from occlusal surface
Δ = exosylid in wear, measured from lowest point of enamel
† = included due to size
* = estimate
>8 = all age groups older than group 8

Table C.3 Heron Eden site third molar data (mm).

Age Group	Specimen	Side	Wear ◊		Metaconid Height	Exostylid Occlusal ¤	Exostylid Enamel Δ
1	2424	R	forming	*†	-		
	6230	L	forming	*†	-		
	6826	L	forming	*†	-		
	8522	L	forming	†	39.2		
2	2130	L	forming	*†	-		
	2680	L	forming	*†	-		
	2701	R	forming	†	66.8		
	3029	L	forming	†	68.3		
	3385	R	forming	*†	-		
	3419	R	forming	*†	-		
	5817	R	forming	†	62.0		
3	8535	R	I-IV		64.2		
	9262	L	I-IV		63.2		
4	8476	L	I-VII		64.9		
	8715	R	I-VI		64.6		
5	47	R	hypo.		62.1		
6	690	L		*	-	30.2	
	2131	R		*	57.6	12.7	
	2340	R		*	56.9	33.8	
	2457	R		*	56.0	14.0	
	3066	L		*	54.5	9.8	
	3076	R		*	55.0	9.5	
	3417	R		*	57.2	9.6	
	6405	L		*	56.7	12.1	
	8909	L		*	56.9	8.5	
	9659	R		*	54.3	12.0	

continued

Table C.3 (continued) Heron Eden site third molar data (mm).

Age Group	Specimen	Side	Wear ◊	Metaconid Height	Exostylid Occlusal ¤	Exostylid Enamel Δ
7	1028	L	*	50.5	3.3	
	2518	L	*	50.5	4.2	
	3046	L	*	53.1	10.5	
	3049	R	*	53.0	12.9	
	3266	R	*	51.2	4.0	
	4873	L	*	52.5	6.8	
	5215	R	*	52.0	5.8	
	5413	R		49.4	13.7	
	5975	R	*	48.0	4.9	
	6846	L		49.9	8.3	
	8376	L	*	51.2	4.7	
8	328	L	*	43.0	4.0	
	1328	L		46.4		38.2
	1565	R	*	-	7.3	
	5187	L		44.0		
	8180	R	*†	-	9.2	
	9219	L		44.4	1.6	
	9225	R	*	45.4	3.0	
>8	5715	R		35.7		26.1
	7403	R		23.9		18.4
	7404	L		21.1		13.4
	8521	L	*	35.8		28.7
	8625	R	*	35.2		28.0

◊ = description of tooth cusps coming into wear
¤ = exostylid measured from occlusal surface
Δ = exostylid in wear, measured from lowest point of enamel
† = included due to size
* = estimate
>8 = all age groups older than group 8
hypo. = hypoconulid